METALS & ALLOYS

Registered in the U. S. Patent Office

The Magazine of Metallurgical Engineering

INCLUDING
CURRENT METALLURGICAL ABSTRACTS

VOLUME 3

FEBRUARY
1932

NUMBER 2

$3.00 a Year

40 Cents a Copy

INDUSTRY'S LIGHTEST METAL

NOW AVAILABLE *in* DIE CASTINGS

SAVES
another 35%
weight in
DIE CAST PARTS

DOWMETAL, industry's lightest structural metal, is proving a boon to die casting manufacturers.

It produces clean, sharp corners and gives longer life to the dies.

Threads, cored holes, lugs and other design factors are easily accommodated.

Dowmetal is a third lighter than any other alloy and only a fourth the weight of zinc-base alloys.

Yet, despite its extreme lightness, it possesses ample strength and rigidity.

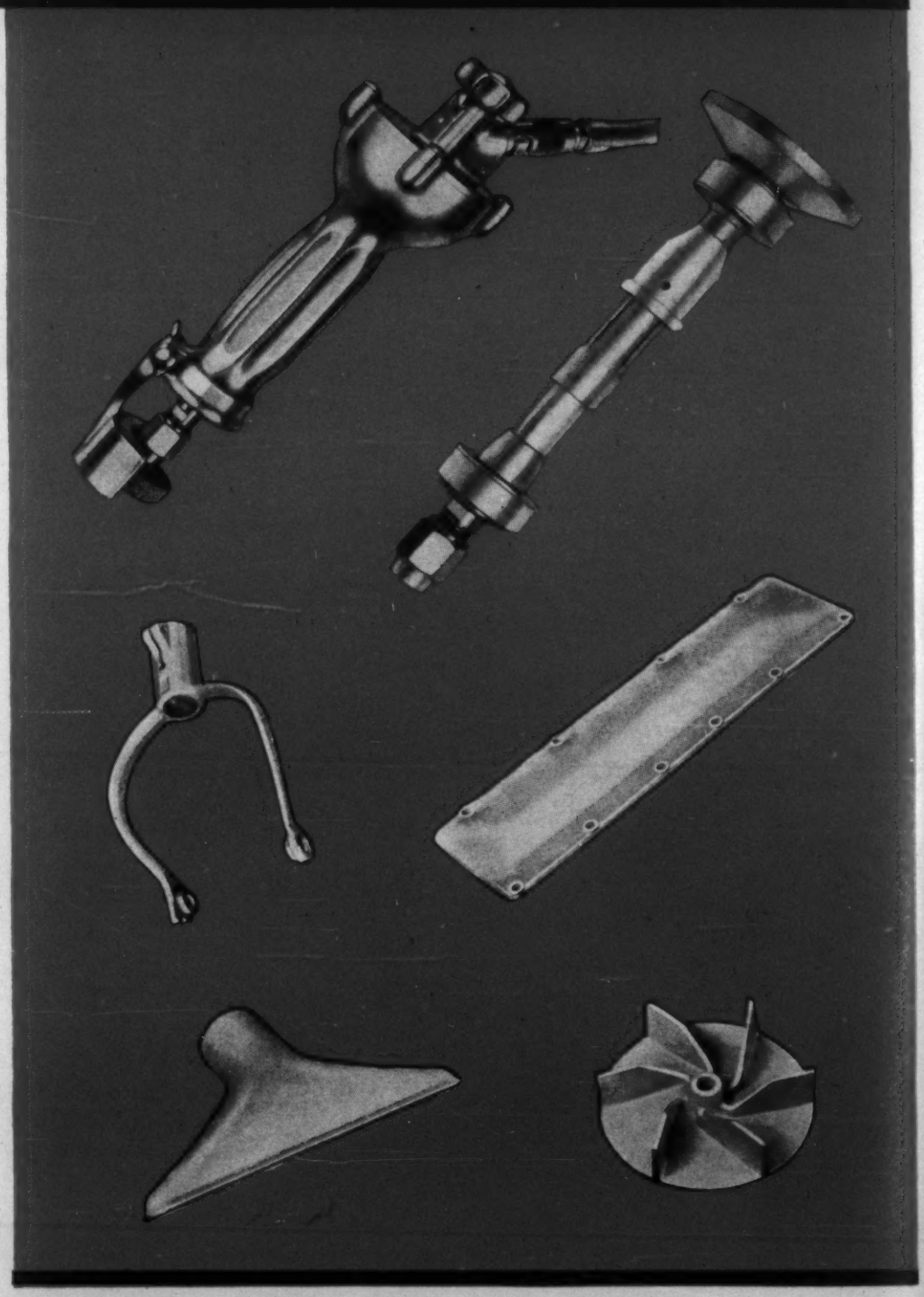
Elimination of excessive weight in the rotor of the Air Grinder (illustration at upper right) simplified the problems of a portable tool manufacturer. It provided lightning-fast pick-up, eliminated vibration and reduced the gyroscopic action.

Dowmetal can also be rolled, forged, extruded, cast, and welded by methods common in industry.

Write for copy of Dowmetal Data Book.

Dowmetal Division

THE DOW CHEMICAL COMPANY
MIDLAND, MICHIGAN



NOW YOU CAN MAKE IT OF

DOWMETAL
MAGNESIUM ALLOYS

Take Useless Dead Weight Out of Your Products

METALS & ALLOYS

The Magazine of Metallurgical Engineering

H. W. GILLETT, Editorial Director
Battelle Memorial Institute,
Columbus, Ohio

RICHARD RIMBACH, Editor

EDITORIAL OFFICE:
3619 Forbes St., Pittsburgh, Pa.

All Editorial correspondence should be sent to the above address

◆

Editorial Advisory Board

H. A. ANDERSON
Western Electric Company
W. H. BASSETT
American Brass Company
A. L. BOEGEHOLD
General Motors Corporation
P. H. BRACE
Westinghouse Electric & Mfg. Co.
R. A. BULL
Electric Steel Founders' Research Group
O. W. ELLIS
Ontario Research Foundation
JUNIUS D. EDWARDS
Aluminum Company of America
H. J. FRENCH
International Nickel Company, Inc.
S. L. HOYT
A. O. Smith Corporation
J. B. JOHNSON
Wright Field, Air Corps, War Department
JOHN JOHNSTON
United States Steel Corporation
JAMES T. MACKENZIE
American Cast Iron Pipe Company
JOHN A. MATHEWS
Crucible Steel Company of America
C. A. McCUNE
Welding Engineering & Research Corporation
W. B. PRICE
Scovill Manufacturing Company
H. A. SCHWARTZ
National Malleable & Steel Castings Company
F. N. SPELLER
National Tube Company
L. W. SPRING
Crane Co.
JEROME STRAUSS
Vanadium Corporation of America

◆

WM. P. WINSOR, Advertising Manager

ADVERTISING OFFICES:
MAIN OFFICE, 3619 Forbes St., Pittsburgh.
CHICAGO, 1050 Straus Bldg.
CLEVELAND, 953 Leader Bldg.
NEW YORK, 419 Fourth Ave.
SAN FRANCISCO, 381 Bush St.

◆

PUBLISHED MONTHLY BY THE CHEMICAL CATALOG COMPANY, INC.

Ralph Reinhold, Pres.-Treas.
Philip H. Hubbard, Vice-Pres.
H. Burton Lowe, Vice-Pres.
Francis M. Turner, Vice-Pres.

◆

Annual Subscription: U. S., Possessions, Mexico and Cuba, $3.00; All Other Countries, $4.00.

All communications relating to subscriptions or back issues should be addressed to METALS & ALLOYS, 419 Fourth Avenue, New York.

Copyright, 1932, by The Chemical Catalog Company, Inc. All rights reserved.

CONTENTS—FEBRUARY, 1932

Press Casting—Its Relation to Die Casting and Permanent Mold Casting 29
Charles Pack

Recent Progress in Heat Treatment of Ball Bearing Races . . 38
Haakon Styri

Early Chemistry and Chemists in the Iron and Steel Industries of America 40
L. W. Spring and L. E. Gilmore

The Iron-Beryllium System 43
R. H. Harrington

A New Rustless Iron Alloy 49
R. P. De Vries

Editorial Comment . . . 27 **Readers' Comments** . . . 28

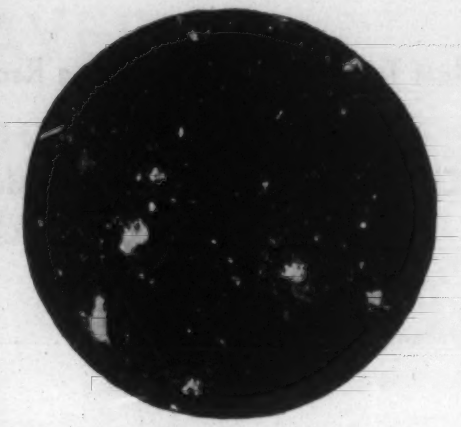
CURRENT METALLURGICAL ABSTRACTS

General MA29
Properties of Metals MA29
Properties of Non-Ferrous Alloys MA30
Properties of Ferrous Alloys MA31
Corrosion, Erosion, Oxidation, Passivity & Protection of Metals & Alloys MA32
Structure of Metals & Alloys MA34
Physical, Mechanical & Magnetic Testing MA37
Electro-Chemistry MA38
Metallic Coatings Other than Electroplating MA39
Industrial Uses & Applications MA39
Heat Treatment MA41
Joining of Metals & Alloys MA42
Working of Metals & Alloys MA44
Defects MA45
Chemical Analysis MA45
Historical & Biographical MA46
Economic MA47
Plants & Laboratories MA47
Machinery & Supplies MA48
Bibliographies MA48
Miscellaneous MA48
Laboratory Apparatus MA49
Foundry Practice & Appliances MA50
Effect of Temperature on Metals & Alloys MA51
Leaching MA52
Reduction Metallurgy MA52
Non-Metallic Coatings for Metals & Alloys MA52
Manufacturers' Literature Reviews MA53

No. 1 of a Series

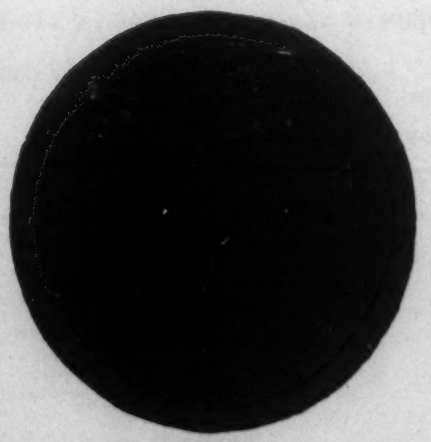
PUNCH FOR BINDER

Microphotos (6 times) of Nickel-Chrome platings on Zinc after continuous outdoor exposures equal to two years normal outdoor service. Corrosion is shown by white; black shows total reflection of uncorroded surface.



.00015″ Ni.
.00002″ Cr.

.0003″ Ni.
.00002″ Cr.



.0005″ Ni.
.00002″ Cr.

PLATING ZINC

for Outdoor Exposure

Chromium plating over a primary coat of nickel on rolled zinc or zinc die castings has become common practice in the past few years. Long exposures have proved these coatings perfectly satisfactory when proper specifications are followed.

Specifications:

From the accompanying photomicrographs of coatings of various thicknesses after exposures equal to approximately two years normal service, it is plainly seen that a minimum average thickness of .0003″ of *deposited* nickel should be specified. And this limit should be rigidly maintained.

Measurement of Coating Thickness:

Three methods have been developed for the determination of the thickness of coatings:

(1) Measurement of the coating after the zinc base has been dissolved with acid. Special micrometers have been developed for this work. Ordinary micrometers are not satisfactory.

(2) A measured specimen can be dissolved in acid and a rapid nickel quantitative determination made; from which the coating thickness can be calculated.

(3) Microscopic measurement can be made at high magnification by means of a micrometer eyepiece.

All three of these methods have been thoroughly investigated and are found to agree closely in their results.

The complete plating procedure recommended by the Research Division of The New Jersey Zinc Company and published in the booklet, "The Plating of Rolled Zinc and Zinc Die Castings", will be gladly furnished upon request.

New Jersey Zinc® 160 FRONT ST., NEW YORK **THE NEW JERSEY ZINC CO.**

EDITORIAL COMMENT

Then, Now and Hereafter

ANYONE who likes his work is interested in the history of things relating to that work, and especially in the history of pioneer days, when in spite of the hardships and difficulties encountered, crude ideas or crude mechanisms were born that with the passage of time developed into modern, more fully perfected ones.

The musician will pause, as he turns the pages of the encyclopedia, to read a description of early Egyptian musical instruments. The hunter finds fascination in the story of the development of the Kentucky rifle. One did not even have to be a railroad man to enjoy and appreciate the Baltimore and Ohio's Centenary of the Iron Horse.

The study of the history of metallurgical engineering may not, it is true, be of direct technical help to the reader, and there are those who would consider space given to the subject in METALS & ALLOYS as wasted. But we think that for one who may take that view, there are a hundred whose interest in the metals they deal with is such that they will consider it a happy relaxation to read about early developments in their profession. Moreover, the example of what was accomplished under difficulties may well serve as an inspiration for present and future metallurgists.

Believing this, we have already published some articles of a historical flavor. In Vol. 1, No. 1, of July 1929, Dr. Jeffries discussed "Two Decades of Precipitation Hardening Alloys," in January 1930, Professor Boylston told the story of "Fifty Years of Physical Metallurgy," and Mr. Wadhams described the early history of the nickel industry in the September 1931 issue.

METALS & ALLOYS is anxious to collect and publish more historical material, articles, reminiscences and notes dealing with the development of metallurgical engineering in America.

Time slips away, and the facts of greatest human interest tend to pass into obscurity. Unless some definite effort is made to put on record facts known to some of the metallurgical pioneers now living, it will become increasingly difficult to assemble a true historical record. Particularly does this apply to the sort of thing that doesn't ordinarily get recorded in technical or scientific publications.

While many interesting historical points relating to the cast iron industry were brought out in Dr. Moldenke's books, yet how many of his personal experiences in his pioneer work there must have been that we would like to hear about, but which are now beyond recording?

Some of our Editorial Advisory Board are interested in getting that sort of thing, as it relates to metallurgy, on record before it is too late, and we expect to sprinkle historical articles in among the technical and scientific ones in the future. In this issue, Spring and Gilmore begin a series of articles dealing with the entrance of science, in the form of chemistry, into the American iron and steel industry. In those (and in much later) days, metallurgists were not specially trained as such, but generally developed themselves after having had chemical or engineering training, and getting into service in a metallurgical industry.

Besides this series, other articles dealing with individual metallurgical organizations will appear.

It is hoped that corrections and additions to these various articles, in which accuracy and completeness are difficult to attain because of lapse of time and lack of documentation, will be sent in by readers who may be able to round out the history. Reminiscences, of a technical or a personal nature, old photographs or interesting documents relating to the development of American Metallurgy and the lives of pioneer American metallurgists, could be brought out of oblivion to serve as an inspiration to the younger generation if those who know where they may be hidden will help us to unearth them. We ask the aid of our readers in this effort to preserve these fragments from which American metallurgical history can be built up.

Nor is it necessary that an event be very old, to be interesting history. We are sure that in their service behind the lines, during the World War, American metallurgical plants and metallurgists had many experiences in doing the apparently impossible in an unbelievably short time, that deserve recording, but have not been recorded. Even now it will not be easy to assemble the records of these cases, and it will get harder as time goes on.

Two passages from Vergil have stuck with us ever since our school days: "Varium et mutabile semper femina," and "Forsan et haec meminisse juvabit." The first doesn't strike us now as particularly profound or truthful, but the second is both. Not only "perchance," but indeed, it will be pleasant to remember these things. Let's get them down in black and white before they are forgotten.—H. W. GILLETT

Romance and Metallurgy

TWO of the most outstanding American metallurgical engineers have recently given talks of a non-technical nature on metallurgy that are most interesting. If your wife or your boy cares to know why you, as a metallurgical engineer, find your work fascinating, give them these talks to read.

One is by Dr. Mathews[1] on "The World of Metallurgy," and bears as a sub-title "The Romance of Metallurgy," while the other by Dr. Jeffries[2] is entitled "The Romance of Metals and Alloys."

We strongly suspect that one potent reason why these men stand in the front ranks of the world's metallurgical engineers is because they are of the type who do appreciate the romance of metallurgy, and to whom their chosen profession is an intensely fascinating one, a continual joy, not merely a means for a livelihood.

We cannot abstract these talks without losing their flavor; they should be read in the originals; yet we can briefly mention some of the things that impress these leaders as showing that there is romance in metallurgy. Dr. Jeffries is impressed by the fact that "we cannot escape metals without escaping civilization;" transportation and communication, the vital factors in changing man from an individualist to one dependent on many others who, though far away geographically, become neighbors in modern civilization, are made possible by modern alloys. For the serving of man's manifold needs, 5000 alloys, substantially different in composition, are required. Pointing out that the magical changes in properties brought about by heat treatment of steel and duralumin, and by cold working, produce in a given alloy new sets of properties, Dr. Jeffries concludes that there are in use tens of thousands of alloys with different sets of properties, and industry is still crying for more.

He shows the modern tempo in metallurgy by contrasting the century and a quarter that elapsed between the time metallic tungsten was produced in 1783 and that when it was drawn into wire in 1907, with the fact that but three years elapsed in the case of hafnium, discovered within the last decade, between its discovery and its production in wire form. The same thing occurred with rhenium.

From all this, Dr. Jeffries concludes that there is romance in metallurgy.

Dr. Mathews finds romance in the profitable extraction of one ounce of gold from 64,000 ounces of ore, in the moving of more material annually in the mining of low grade copper ores than was moved in building the Panama Canal, and in the fact that the materials for high speed steel come, the manganese from Brazil or Russia, the tungsten from inland China, the chromium from central Africa, the vanadium from Peru and the cobalt from Australia or Canada, and that the putting of all these together in high speed makes possible the production of Fords and Chevrolets at present prices, i. e., it is the basis of the modern era of large quantity, low-cost manufacturing processes.

Without stating it in so many words, he pleads for a type of metallurgical education that will bring one to see the romance in metallurgy. Instead of too much emphasis on memorizing of detailed facts, he argues for development of an understanding of the underlying principles of science, economics, history and the principles of living and conduct. Even in the study of metallurgy itself, he urges a stimulation of interest, not only in current literature, but also in the history of the subject. The spirit of the past in metallurgy has been the urge to add to mankind's knowledge of the truth, so that future generations may profit, and this must also be the spirit of the present and future.

To those with such a spirit, which Dr. Jeffries and Dr. Mathews alike possess, metallurgy does have romance, indeed.—H. W. GILLETT

[1] The World of Metallurgy. J. A. Mathews, Preprint, Sept. 1931 meeting, *American Institute Mining & Metallurgical Engineers.*
[2] The Romance of Metals and Alloys. Z. Jeffries. Cleveland Engineering, Nov. 19, 1931.

◆ ◆ ◆ ◆ ◆

READERS' COMMENTS

TO THE EDITOR OF METALS & ALLOYS:

The die casting industry is indebted to Mr. Pack for the information in his article on "Press Casting; Its Relation to Die Casting and Permanent Mold Casting" in this issue both for the critical survey which it presents of conventional die casting methods here and abroad and also for the description of "press casting." It is felt, however, that Mr. Pack has over-emphasized the difficulties encountered in using conventional die casting methods due to machine weaknesses, to the exclusion of metal contamination caused by inadequate control of the composition and cleanliness of raw materials purchased by the die caster, or by insufficient care in avoiding contamination of metal in the die casting plant.

The Western Electric Company has consistently adhered to the following composition limits during the past year in the production of aluminum base pressure die castings for telephone apparatus parts.

	A. S. T. M. Alloy No. 4*, %			A. S. T. M. Alloy No. 8*, %		
	Desired	Minimum	Maximum	Desired	Minimum	Maximum
Copper	0.00	...	0.50	1.50	1.00	2.00
Silicon	5.00	4.50	6.00	1.50	0.75	2.00
Nickel	0.00	...	0.50	2.25	1.75	2.50
Iron	0.00	...	1.75	0.00†	...	2.00
Zinc	0.00	...	0.50	0.00	...	0.40
Manganese	0.00	...	0.20	0.00	...	0.20
Magnesium	0.00	...	0.05	0.00	...	0.05
Tin	0.00	...	0.02	0.00	...	0.01
Other impurities	0.00	...	0.10	0.00	...	0.10
Aluminum	95.00	91.50	95.50	94.75	92.50	96.50

* The alloy designations correspond to the standard A. S. T. M. alloys, *Proceedings A.S.T.M.*, Vol. 28, Part I, 1928, page 202.
† This desired percentage has been modified somewhat since adoption of the above limits, as discussed below.

(Continued on Page 46)

PRESS CASTING

Its Relation to Die Casting and Permanent Mold Casting

BY CHARLES PACK*

PRESENT day die castings can't be quite as unsatisfactory for the purposes for which they are appplied as Mr. Pack's article might lead the casual reader to believe, else the use of die cast aluminum alloys and zinc-base alloys would not have reached its present large proportions. It is obvious that die castings are strong enough, sound enough and stable enough to fill a very real need. Yet very extensive work of the A. S. T. M. die casting committee and of some of the forward-looking firms engaged in the business, have been required to bring the die casting art to its present status, and the need for such work is evidence that the die castings of the past, at least, left something to be desired.

One of the difficulties of the die casting business is still that of getting the "weak sisters" among the producers to exercise the known methods of care and control required in the production of high-class die castings, and to so set the stage that the low bidder can be trusted to supply such a product, rather than one that gives the whole industry a black eye. There is still too much danger that a die casting, bought on the low bid basis, may look well on the surface but resemble Swiss cheese beneath.

It is true that in many applications of die castings for ornamental or space-filling purposes, this doesn't matter a bit. In fact, there isn't any good reason why some die castings shouldn't intentionally be made with the maximum blow hole content below a sound skin, to conserve metal. But engineers, having available a cheap way of making castings, naturally want to use the cheap castings for stressed parts, as real materials of engineering construction, so they are calling for dependable, sound and stable die castings. In many cases they are getting them. In some cases where they want them, the design is such that nobody can yet produce them regularly and commercially.

Any effort to remedy this is to be commended. It is logical to make such an effort on the basis of appraising the fundamental difficulties of the older processes so they may, if possible, be avoided. This has been interestingly done by Mr. Pack. It should not be concluded that many of the difficulties mentioned are not being quite successfully overcome in connection with present methods, and we think that even when the press casting process has had its own special difficulties overcome so that its products are perfected, are widely obtainable and have been proven out in quantity production and in service, there will still be a field for die castings.

Nevertheless, there is an upper limit to the field of applicability of present day die castings. Any development that widens the range of alloys that can be used, and that tends to lessen any of the limitations in the casting process itself, is welcome and will be watched with interest. Even if it did nothing more than keep the producers of the present type of product on their toes for steady improvement, it would be useful. Such an article as Mr. Pack's, showing the darker aspects of the present situation, is helpful to the user of the present product by making him realize that die casting is a difficult art, requiring much careful control, and that different producers may differ in their ability to supply the highest possible quality of castings.

THE casting of metals is an art that was known and practiced since prehistoric times. Prior to the Christian Era, metals were cast in baked clay or loam molds, and the first definite improvement in this method of casting was made by Darby in 1720, with the introduction of the method of casting metals in sand molds. Although more than 200 years have elapsed since the introduction of the sand mold, it is nevertheless true that the major volume of metals are to-day cast in sand molds. It is true that tremendous strides have been made in the art of sand casting and that Darby would be astonished were he to see a modern sand foundry in operation, with its automatic sand conditioners, automatic sand conveyors, automatic molding machines, pneumatic core molding machines and the many other labor saving appliances that are considered as necessary adjuncts to the modern sand foundry. Despite these improvements however, the basic principle of casting metals in sand molds has not altered materially during the last two centuries and the products of the sand mold are still comparatively crude.

The advantages of casting metals in metal, or permanent molds, were appreciated long before the advent of the sand mold and the art was practiced at least 200 years prior to the introduction of the sand mold. We find metal molds used for casting printing type and pewter tableware early in the 16th century and we also find lead pipe being cast before the advent of the sand mold. Until the latter part of the 19th century however, the use of the metal mold was limited to the low melting point alloys of tin and lead base. During the 19th century we find the metal mold being used for casting zinc. Such castings were used largely for ornamental parts such as cheap statuary, clock frames and lighting fixtures. The method used, was to pour the metal into the mold by gravity, permitting the casting to solidify and ejecting the casting from the mold. Where heavy sections were encountered, hollow castings were produced by inverting the mold immediately after the pouring of the metal, thereby permitting the unsolidified portion of the metal in the center of the casting to flow out through the gate opening, leaving a shell of solidified metal. This method which is commonly termed "slush casting" is still in use but its application is limited almost entirely to the production of cheap lighting fixtures, statuary and similar articles. Since this paper deals only with those methods of casting that are recognized processes for the production of engineering products, we may discard the "slush casting" process from further consideration.

The beginning of the 20th century was coincident with the advent of the automobile and marks the beginning of what we in this country may term as the "Mass Production Era." With the mass production of automobiles, phonographs and later radio receivers, it is logical that an insistent demand should have been created for a process of casting metals that was more efficient than the sand mold process. This demand was

* Consulting Engineer, New York City.

partially met in this country with the development of what is known as the "Die Casting" process. In Europe, however, the quantity requirements were not as large as in this country and the developments in the art of metal casting generally followed along the somewhat more conservative lines of the casting by gravity pressure in permanent molds.

In this country to-day, we find that outside of the sand foundry we have two methods of producing castings and the resultant products of these methods are commonly termed

A. Die Castings.
B. Permanent Mold Castings.

In Europe, we find these same methods in use. In Germany, for instance, we find the die casting process which is known as "Spritzguss" and the permanent mold process which is known as "Kokillenguss." During the past few years however, the term "Pressguss" has appeared in the German literature, indicating a new method that presumably is a departure from both the die casting and permanent mold processes. Müller[1] has called attention to this new process and indicated wherein it differs from the die casting and permanent mold processes.

The writer is of the opinion that the term "Pressguss" or "Press Casting" will be met with in commercial practice with increasing frequency hereafter and that this method of casting meets a logical demand in the metal casting art which cannot be met by either the die casting or the permanent mold process. The writer will attempt in this paper to outline the basic principles of the press casting process and indicate wherein it differs from the other methods of casting metals in metal molds, that have been used heretofore. In order that the reader may fully appreciate the significance of this new process, it is necessary that the description of this process be preceded by a brief outline of the die casting and permanent mold processes, together with a frank discussion of their advantages and disadvantages.

[1] Walter Müller. Der Messing-Press Guss. *Giesserei-Zeitung*, Vol. 27, Mar. 15, 1930, pages 155–156.

DIE CASTING

The writer[2] in 1914 defined die casting as, "Metal castings, made by forcing molten metal under pressure into a metallic mold or die." This general definition does not differentiate die castings from press castings since both are produced by "forcing molten metal, under pressure, into a metallic mold or die." The difference between the two processes lies mainly in the types of equipment used and the variations in gating practice and other technique necessitated by that equipment. The writer will therefore describe briefly the type of equipment used in the die casting industry in order that the reader may more fully appreciate wherein this equipment differs from that used in the press casting process.

Two general types of machines are used in the die casting process and these are known as (a) plunger machine and (b) goose-neck or air machine. In Fig. 1, is shown a typical example of the plunger machine. Here we have a furnace "b" wherein is contained a metal holding pot "a." The metal is melted in this pot and, immersed in this molten metal, we find a metal pump composed of a cylinder "c" and a piston "g." This piston is attached to a piston arm M^2 which is attached to the piston "g" by means of the groove "g^1." In the position shown in the drawing, the metal in the holding pot "a" is permitted to flow into the cylinder "c" by virtue of the cutout "g^3" in the piston "g." The molten metal then in the cylinder "c" is at the same level as that of the metal in the surrounding reservoir in the pot "a." Attached to the furnace and casting mechanism described above, is a suitable mechanism for holding the two die members "u and v" and for opening and closing the die. In the operation of this particular machine, the entire die and die holder swings around a pivot, describing an angle of 90° and

[2] Charles Pack. Modern Die Casting Practice. *Transactions American Institute of Metals*, Vol. 8, 1914, pages 87–103.

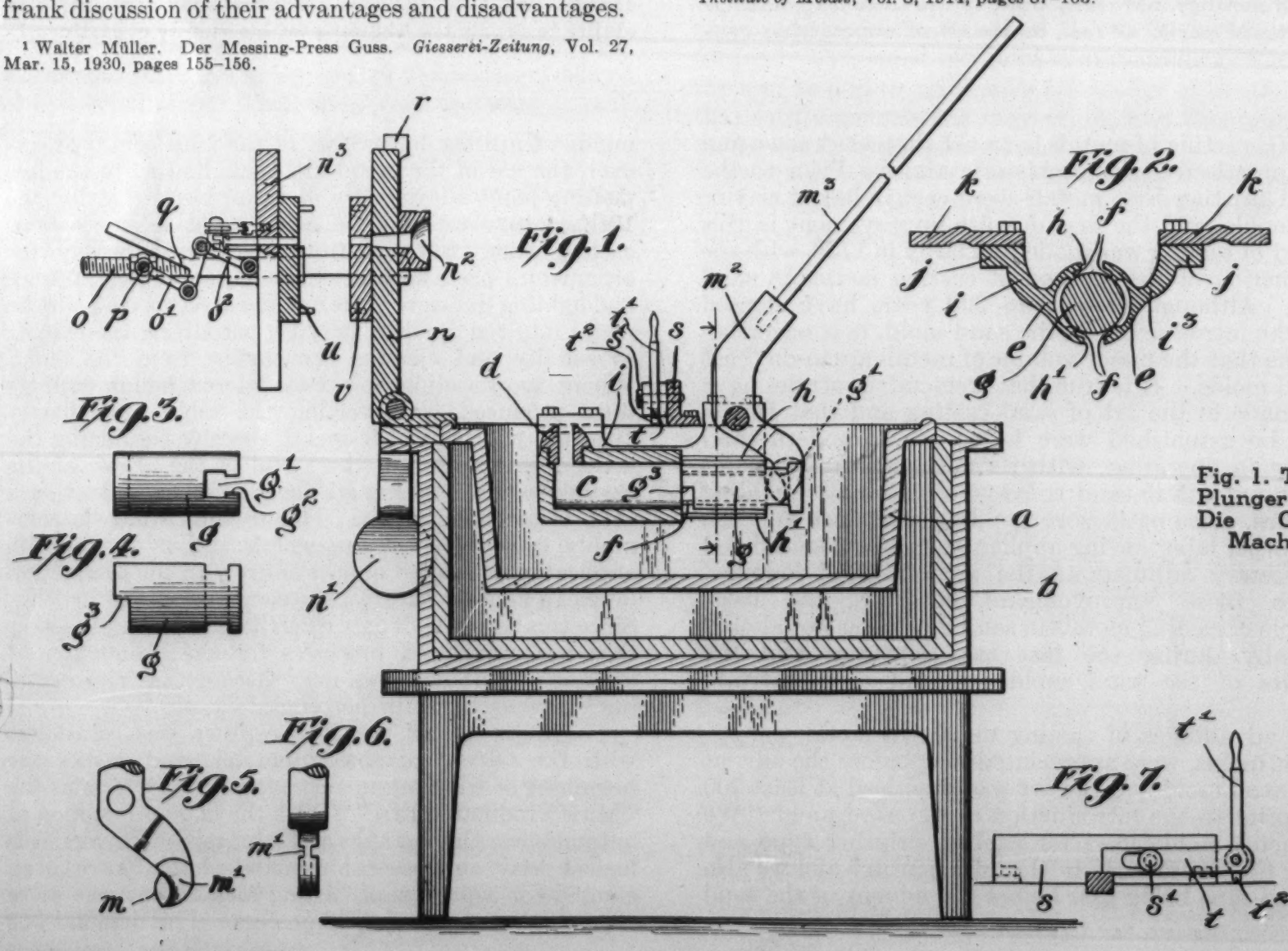


Fig. 1. Typical Plunger Type Die Casting Machine.

in the casting position, the female nozzle N^2 is in close alignment with the male nozzle "d." The metal is forced into the die by the application of power to the lever M^3. This tends to force the piston forward, first closing the opening g^3 and causing the metal contained in the cylinder "c" to be forced into the die through the nozzle and gate channel "N^2."

The machine shown in Fig. 1 is a typical example of the plunger type of die casting machine. There are many modifications of this machine in use. The plunger may be operated vertically instead of horizontally, the swinging of the die and die holder is eliminated on some machines, the die may be opened by means of hydraulic, pneumatic or direct electric motor; the plunger may also be actuated by hydraulic, pneumatic or direct power but all plunger type die casting machines have these factors in common:

A. A die carrier which is attached to a furnace and which holds a reservoir of molten metal.

B. A cast iron piston and cylinder which is immersed in the molten metal. For satisfactory operation, the maximum clearance between piston and cylinder must be held to 0.005".

It is interesting to note that the principle of casting shown in Fig. 1 did not originate with the die casting process. This method of casting was used for casting printing type and pewter as far back as 1860. The first Mergenthaler Linotype machine set up by the N. Y. Tribune in 1889 comprised an automatic type casting machine which in its essential principles was similar to that shown in Fig. 1.

The plunger type of die casting machine will operate satisfactorily with all of the tin and lead base alloys. The die casting industry at its inception adopted this type of machine for the casting of zinc base alloys. Early in the history of the die casting art, it was found that die castings made from tin and lead base alloys had a very limited field of application, due to their rather poor physical properties. Zinc alloys appeared to be the most logical field for the die casting process. The difficulty encountered with most zinc base alloys, was the formation of a zinc-iron alloy (similar to "galvanizer's dross") on the surface of the cast iron parts. This zinc-iron alloy acted as a wedge between the plunger and the cylinder causing the plunger to "freeze" in the cylinder. The remedy for this condition was found in the addition of aluminum to the zinc. Unfortunately, the remedy in this case was, in many ways, worse than the disease. By the addition of aluminum to the zinc, alloys were produced having excellent physical properties when cast, but, since these alloys were subject to varying degrees of deterioration through aging, it became necessary to exercise very close control over the composition and the casting process, to avoid deterioration. It may be stated that no zinc die castings have been produced commercially at any time that did not contain aluminum and that in all such die castings, the problem of instability is present in varying degree. The difficulty has, of course, been overcome so that the alloys used are at least passably suitable for the purpose for which they are employed, or they would not be used. However, the availability of other types of alloys would make it possible to remedy this difficulty with greater ease and certainty.

It would seem quite natural that die casting experimenters should be interested in the application of the die casting process to the higher melting point and more useful alloys, having aluminum or copper as their base metals. The die casting of aluminum alloys was commercially accomplished in 1915.[3] The die casting of aluminum alloys was never commercially practical with the use of a plunger type of machine and this led to the introduction of the "air machine" which is typified by the so-called "goose-neck" machine. A typical example of this machine is shown in Fig. 2.

Here we again start with a melting furnace 6; having an iron holding pot 5 in which a reservoir of the molten aluminum alloy is maintained at the casting temperature. Connected with this furnace and melting pot is the die, mounted on a suitable die carrier and operated in this instance by direct motor. A goose-neck shaped pot or ladle 8, is mounted in such a position that the nozzle 9, can be held securely to a corresponding nozzle in the machine which forms the gate of the casting. The machine shown in this illustration is provided with another nozzle 11, which contacts with an air valve 38. When both nozzles 9 and 11 are clamped tightly in

[3] Charles Pack. Aluminum Die Casting a Commercial Achievement. *Transactions American Institute of Metals*, Vol. 9, 1915, pages 145–158.

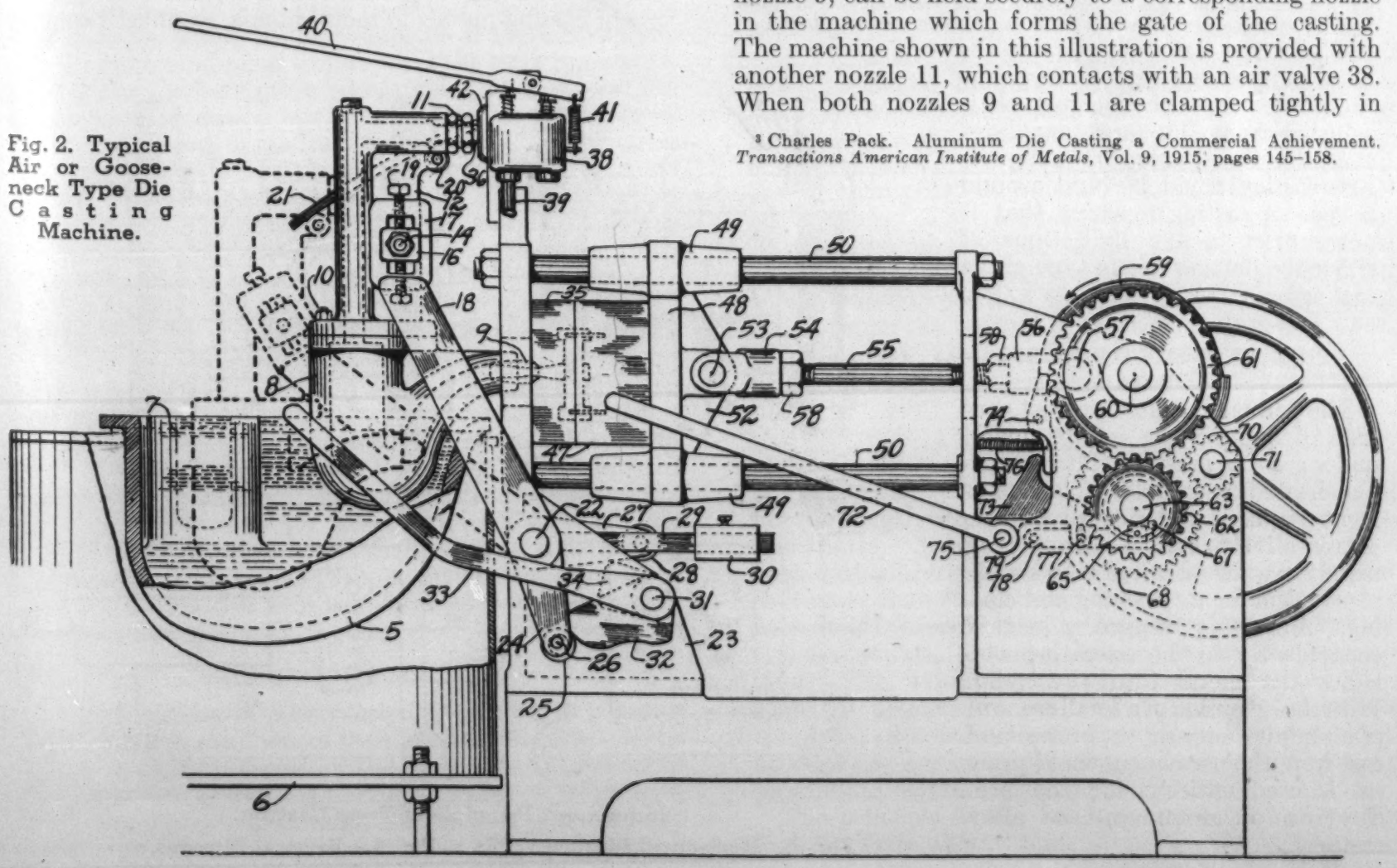


Fig. 2. Typical Air or Goose-neck Type Die Casting Machine.

position, high pressure air enters through the nozzle 11 and is impinged on the surface of the molten metal in the goose-neck, forcing the metal into the die. After the "shot" has been made, the goose-neck is dropped to the position shown by the dotted lines. The nozzle 9, now being below the surface of the molten metal in the reservoir, acts as an inlet nozzle, permitting the goose-neck to be refilled by gravity pressure, while the casting is being ejected from the die. Whereas many modifications of the machine shown in Fig. 2 are in commercial use, it may be stated that this machine, in principle, is used for almost the entire production of aluminum base die castings and also for an appreciable percentage of zinc die castings. The objection to the use of this machine may be summarized as follows:

1. The contamination of the alloy with iron due to the solvent action of the molten metal on the iron parts in contact with it. This is particularly objectionable with aluminum alloys, where, unless care is exercised, the iron content may run up to 3 or 4%, though current specifications set the limit at 2 or 2½%.

2. The goose-neck nozzle passes through a surface layer of dross during each casting operation, picking up and injecting an appreciable quantity of oxide into the die. This is particularly objectionable with aluminum alloys where the oxide is highly abrasive. So-called "black diamonds" are frequently met with in machining aluminum die castings and consist of occluded lumps of aluminum dross. The hard inclusions met with in aluminum die casting are of two types. One consists of iron scale from the pots and goose-necks. This is not met with as frequently as the gray inclusion which seems to consist of a mixture of Al and Al_2O_3. On polishing, this gray inclusion may often be seen very distinctly in the form of streaks over the entire casting.

3. The operating pressure is limited to about 500 lbs./in.^{2} which may be assumed as a maximum for compressed air. Higher pressures are exerted upon the metal in some plunger type machines and the higher the pressure, the better the surface and the greater the soundness of the castings. Even at this pressure it is conceivable that the charging of a red hot cast iron chamber with this pressure must be a dangerous proceeding. It may be reasonably assumed that the pressure casting art of the future should not be limited to casting pressures of 500 lbs./in.^{2} nor even 5000 lbs./in.^{2}

4. One of the main objects of pressure casting is the production of accurate castings. It is self-evident that the production of accurate castings must require an accurate die and an accurate machine. It will be easier to maintain accurate alignment of the die members if the melting furnace is removed from the machine itself so that its heat does not tend to produce mis-alignment.

The writer has merely given the most outstanding drawbacks to the use of this type of machine. It is assumed from the foregoing, however, that an improved art of pressure casting might be built around a type of casting machine that is not subject to the limitations of either the plunger or air type of die casting machine.

PERMANENT MOLD PROCESS

The permanent mold process consists of pouring the molten metal under gravity pressure, into a suitably heated die or mold. The equipment required for this process is comparatively simple consisting merely of a die mounted on a simple mechanism for its opening and closing. A melting furnace is located conveniently to the operator, who ladles the metal into the mold. With the exception of a small amount of aluminum bronze, tin bronze and cast iron, the permanent mold process is used entirely for the production of aluminum-base alloy castings.

In accuracy and detail, a permanent mold casting may be stated to be halfway between a sand casting and a die casting. As a general rule, it may be stated that it is not possible to produce castings by the permanent mold process with as thin a wall as in the die casting process. Furthermore, by the die casting process it is possible to cast small holes, slots and threads that could not be cast in the permanent mold process. The speed of operation is also much greater in the die casting process than in the permanent mold process. The greater speed of cooling the casting in the die casting process also tends to produce proportionately stronger castings than by the permanent mold process.

Despite these obvious disadvantages of the permanent mold process, it is safe to say that a larger quantity of aluminum alloys is being cast by the permanent mold process than by the die casting process. The reason for this situation can be more fully appreciated by a consideration of the objectionable features of aluminum die castings.

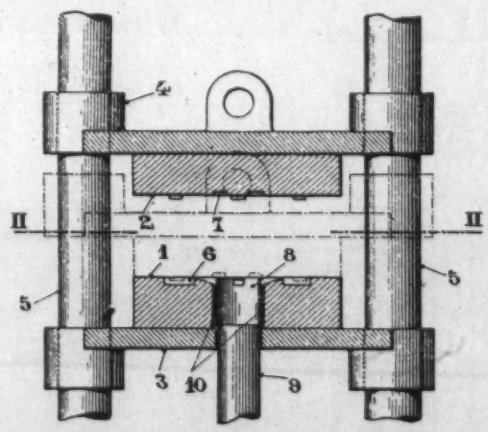
1. High Iron Content. By the permanent mold process the iron content can be more easily controlled whereas in the die casting process it requires special care to maintain the iron content below 2.5%.

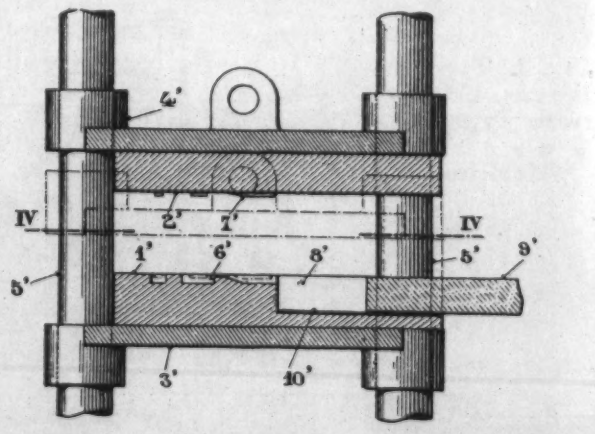
2. Hard Spots. Aluminum die castings requiring subsequent machining or polishing, may exhibit "hard spots" due to dross inclusions, which are objectionable.

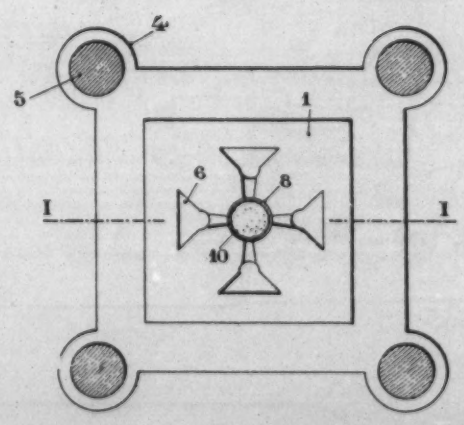
3. Blowholes. Where die castings require subsequent machining, blowholes of appreciable size are often encountered. Where the casting requires subsequent heat treating, these blowholes tend to break through the surface of the casting in the form of unsightly "blisters."

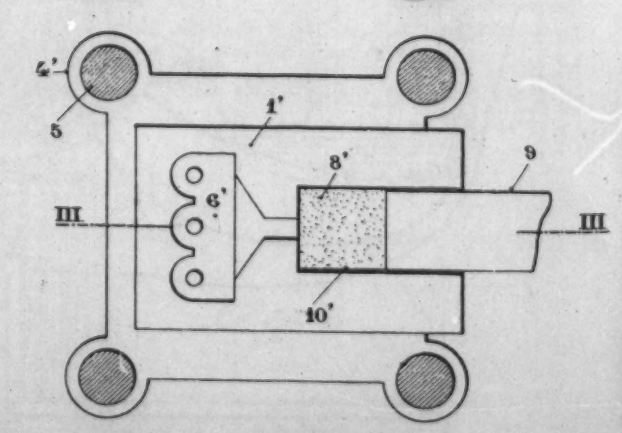
It may be safely stated that if aluminum die castings could be produced, that were free from the objections noted, the permanent mold process for casting aluminum would be eliminated from the metal working art, when quantity production is required.

From a careful consideration of the foregoing facts, we arrive at the conclusion that neither the die casting process nor the permanent mold process as they are now constituted offer the ultimate solution to the problem of casting metals in metal molds. It must also be quite evident from the foregoing, that if we are to extend the art of casting metals in metal molds, we must begin by









Jaquemont Principle of Press Casting.

Fig. 3. Horizontal Plunger. Fig. 4. Vertical Plunger.

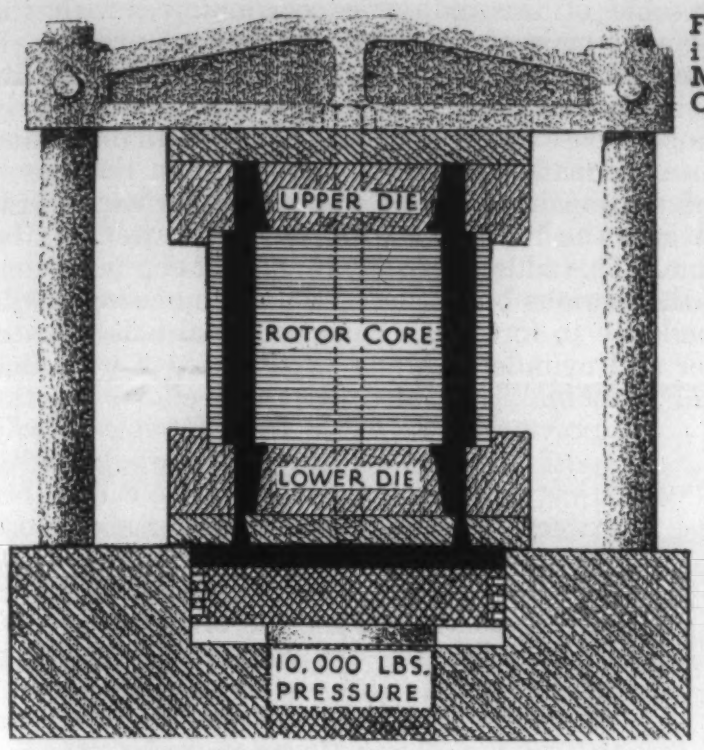


Fig. 5. Westinghouse Method of Casting Rotors.

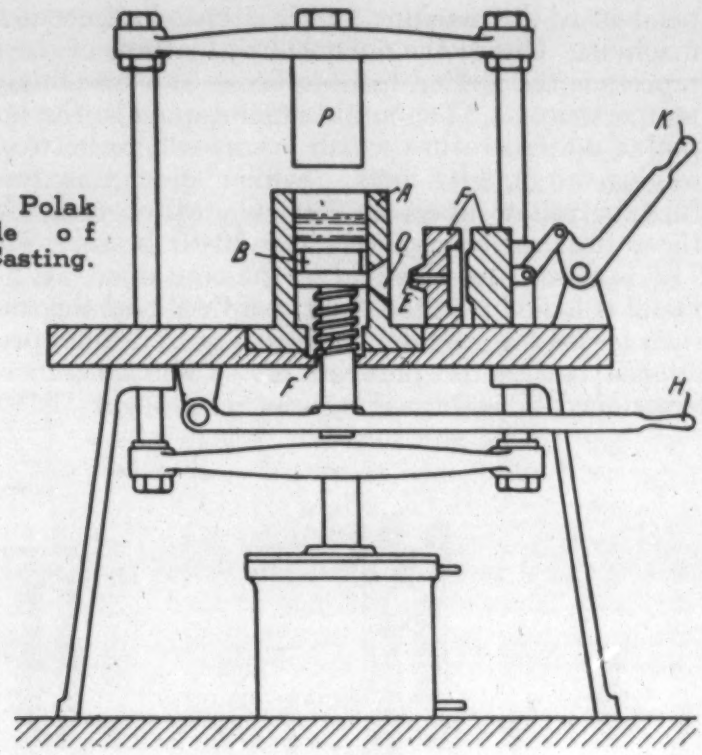


Fig. 6. Polak Principle of Press Casting.

either eliminating the objectionable features of the die casting process or find means of applying pressures to the permanent mold process to enable us to produce castings that, in accuracy and detail, are comparable with die castings, without sacrificing the desirable properties of the permanent mold castings. It is the writer's opinion that press casting offers that medium of attaining this desirable goal. In the description of the press casting process which follows, it will be evident that this process combines many desirable features of both the die casting and permanent mold processes and is not subject to all the limitations of either process.

PRESS CASTING

The term "press casting," as has already been noted, has been used in European technical literature during the past few years but it is doubtful if there exists any clear understanding as to just what the term represents. The name has heretofore been applied to brass and the erroneous impression has been created that brass press casting is a new name for brass forgings. Brass press castings are made directly from the molten metal in one operation, whereas the manufacture of brass forgings requires the intermediate step of the conversion of the molten metal into wrought bar or special shapes. Press casting is purely a casting process.

It is difficult to trace the origin of any name but the writer is of the opinion that the name was first applied by Joseph Polak of Prague, Czechoslovakia, to a brass product produced on his machine, which will be described below. In principle, press casting is not new since, in a general way, this type of equipment has been used for special work for many years. Recent experimenters, however, have succeeded in the development of equipment for general purposes which are equal to, if not more efficient than the present die casting machines. The writer will endeavor to describe a number of machines that have been used for the production of press castings.

JACQUEMONT MACHINE

This machine, in construction, is similar to a power press, the two members of the die being mounted on the upper and lower platens of the press. In the center of the lower die, a cavity is provided, which registers with a plunger operating through the bottom platen of the press. In the practical operation of this machine it is necessary to insulate the walls of the casting cup 8 (Fig. 3) which is best accomplished by placing therein a cup formed from sheet asbestos.

The metal holding pot is placed adjacent to the machine but is entirely independent of the machine. The casting operation is carried out as follows:

A cup formed from asbestos paper is placed into the cavity 8, the metal is poured into this cup, the die is closed and the plunger 9 is brought upward forcing the metal into the cavities of the die. Any excess metal poured into the cup solidifies and is removed with the casting. Fig. 4 illustrates a modification of this principle using a rectangular plunger, which operates horizontally. The Jacquemont machine is operated hydraulically. The plunger, which projects above the surface of the lower platen, is operated by an hydraulic cylinder.

In Fig. 5 is shown the method used by the Westinghouse Electric & Manufacturing Co. for casting rotors. Here, a series of laminated rotor cores are placed between the upper and lower die members. These laminated rotor cores are provided with perforations and the molten pure aluminum is forced through these perforations. The method used is similar to the Jacquemont method described above. The molten aluminum is poured into a suitable well, the laminated core is placed in position, the die is closed and the piston, which forms the bottom of the well is forced upward, which tends to force the molten aluminum through the perforations and the resultant product is the complete rotor.

POLAK MACHINE

The Polak machine was designed by Joseph Polak of Prague, Czechoslovakia primarily for the production of brass parts. As a brass machine, the Polak machine has been eminently satisfactory, as evidenced by the fact that more than 80 of these machines are in operation in such countries as England, Germany, Sweden, France, Czechoslovakia, Holland, Russia, Japan and Switzerland. The writer is authoritatively informed that some 20 machines have been contracted for in this country and that at least three companies of national prominence are now installing these machines for the production of brass press castings.

The principle of the Polak machine is illustrated in Fig. 6. Here also, the metal melting furnace is inde-

pendent of the machine and is situated adjacent to the machine. One of the outstanding features of the Polak process is the ability to cast brass at exceedingly low temperatures. The metal is maintained in the holding pot at a temperature which is somewhere between the solidus and liquidus lines. Müller[1] gives this temperature for yellow brass as 850° C., which is below the theoretical melting point of a 60-40 brass. The die "F" is closed and clamped to the container "A." The metal is ladled into the container "A" and the metal is then forced into the die by means of hydraulic pressure applied behind the plunger "P." The bottom of the container "A" is formed by another plunger "B" which

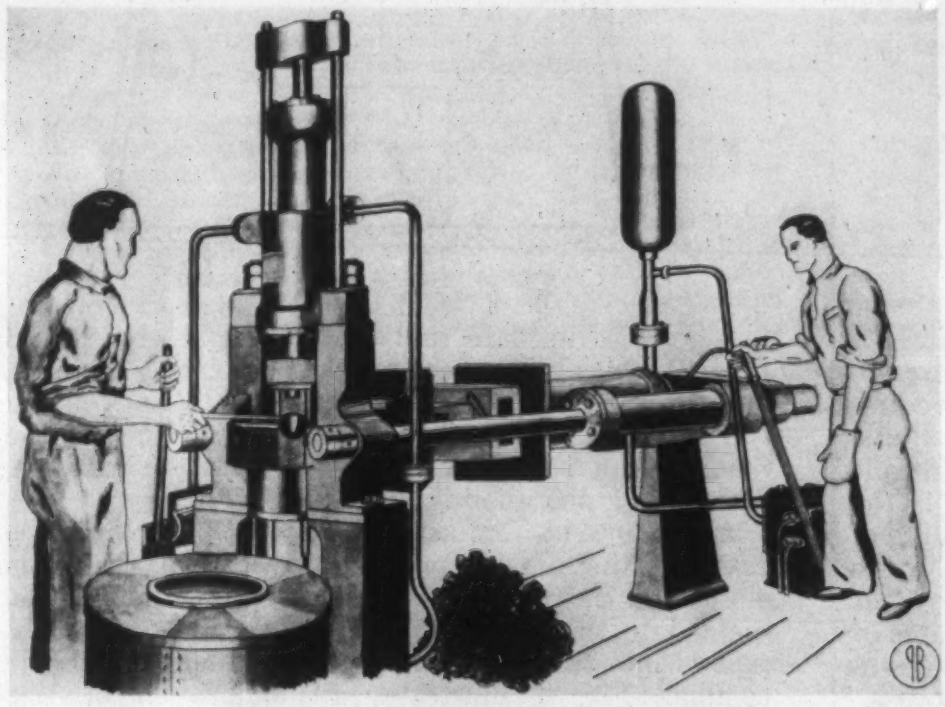


Fig. 7. Polak Press Casting Machine.

serves a number of purposes. When casting brass or any other metal in the semi-fluid state, this plunger may be used for the purpose of shearing off the residue of metal remaining in the container from the main gate and for the purpose of ejecting this residual disc of metal from the cup, whereas the main gate is ejected with the casting.

When casting metals or alloys that have a sharply defined melting point, such as pure metals or eutectic alloys, the metal will flow through the opening "O" and partially fill the die cavity before the pressure is applied. This would result in unsatisfactory castings. Polak resorts to the rather ingenious method of using the plunger "B" for a gate "shut off." The construction of the latest Polak machines permits of setting the plunger "B" in such position, before pouring the metal into the container, that the plunger will shut off the opening "O." This position of the plunger is clearly shown in the accompanying illustration. When the metal is poured into the container and the pressure is applied, the first effect of the pressure is to force the plunger downward, permitting the metal to be forced into the die.

A view of an assembled "Polak" machine is shown in Fig. 7.

PACK MACHINE

The Pack machine, in appearance and general construction, resembles the Jacquemont machine more closely than the Polak machine.

In order to grasp the significance of the casting principle of the Pack machine, it is necessary to understand some of the difficulties encountered with the Jacquemont type of machine. In general practice, it has been found impossible to get any practical results with the Jacquemont type of machine, particularly with copper base alloys, without the use of an insulating cup, usually made from sheet asbestos. In the operation of the machine one of these asbestos cups is inserted into the metal well for each operation of the machine. This adds materially to the cost of production.

Another serious objection to this type of machine is the tendency to force thin chips of metal between the plunger and cylinder. Many experimenters with this type of machine have directed their efforts to the prevention of metal from forcing its way past the plunger since this would mean that a "fin" of metal would be caught between the plunger and cylinder and cause the plunger to bind. A closer examination of the Westinghouse principle shown in Fig. 5 will reveal the use of packing rings, presumably for the purpose of preventing leakage of molten metal past the piston when the pressure is applied. There are also a number of European patents on record having the same objective. It may be stated that this type of machine will not function in a practical manner unless provisions are made to prevent any metal from getting in between the plunger and cylinder or unless provisions are made for the automatic ejection of any metal that may be caught here.

It may also be stated, as a general principle, that when working with the higher melting point metals, it is not practical to maintain any close fit between the plunger and cylinder. Normal variations in machine construction and inequalities due to expansion of the machine parts under heat, tend to create excessive wear of the plunger and cylinder if fitted to any close tolerance.

The casting principle of the Pack Machine is shown in Fig. 8. The well "C" is mounted in a suitable press adjacent to one member of the die "A." The plunger "P" forms the bottom of the well "C" and is capable of being forced upward and downward by means of hydraulic pressure. The plunger "P" does not contact with the sides of the well. Sufficient clearance may be allowed between the plunger and the well to compensate for any errors in machine construction and variations in expansion of the machine parts. The machine will operate with clearances of $^1/_{16}$" even though extremely high casting pressures are used. In practice, this clearance may be made sufficient to prevent any contact of the plunger with any part of the casting well. It will also be noted that, in addition to the clearance between the well and plunger, the well is tapered upwardly which acts as additional clearance.

The metal is poured into the well and the operator, by merely pressing a button, insures the proper timing and sequence of the operations. The temperature of the metal and the temperature of the well are maintained in direct relation to the speed of the machine so that the following will occur:

The metal is poured into the well and, since the temperature of the well is below the melting point of the metal, the metal will immediately begin to solidify wherever it contacts with the well. It will be noted that this tends first to effectively seal any gap between the plunger and the well. The time that elapses between the pouring of the metal into the well and the upward stroke of the plunger is positively controlled by

the machine in such a manner as to permit the formation of a solidified cup (shown by the heavy line) in which is contained the molten metal to be cast. The upward movement of the plunger "P" tends to raise the entire cup of molten metal, with its solidified exterior, until it contacts with the other member of the die "B," when it collapses, causing the liquid metal from the inside of the cup to flow through the gate "G" into the cavities of the die.

It is quite evident that the three factors controlling the satisfactory operation of this machine are:

1. Temperature of metal
2. Temperature of well
3. Speed of operation.

It is also evident that the successful operation of this machine depends upon the formation of a solidified outer crust of metal, which tends to seal the opening between the plunger and the well. It is quite conceivable that, with adverse conditions such as superheated metal and the superheated well, the metal may be shot out from the bottom of the well, leaving a layer of metal between the well and the plunger. Unless this layer of metal is removed before the next operation, it will tend to prevent the free movement of the plunger and will cause rapid erosion of the plunger or cylinder or both.

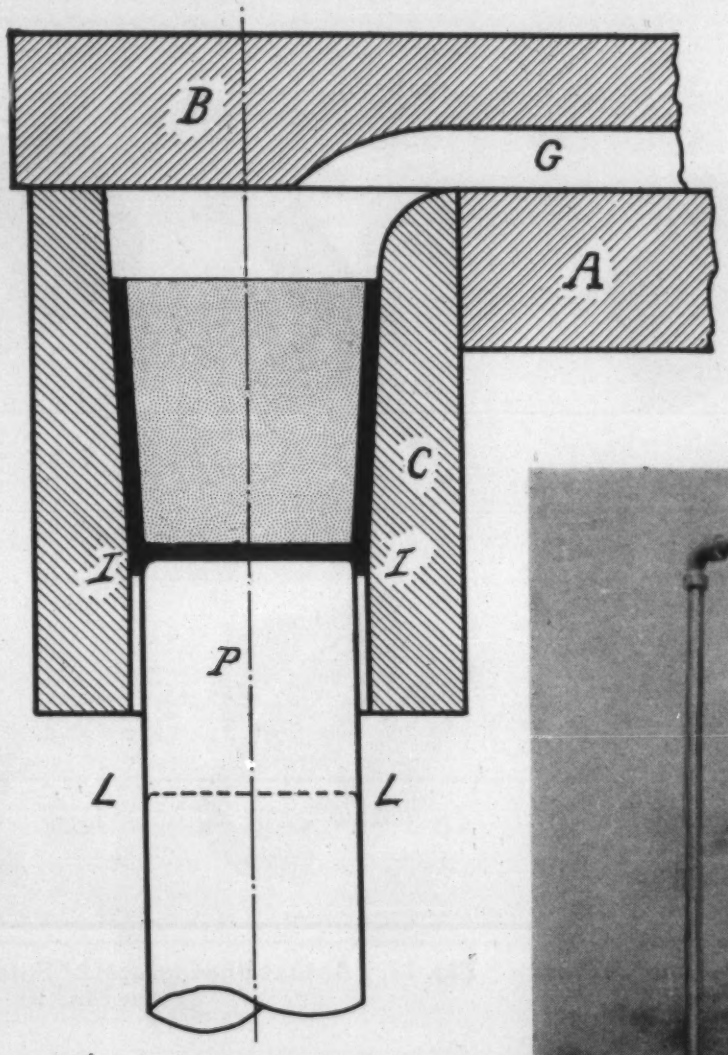


Fig. 8. Pack Principle of Press Casting.

There are 4 normal operations involved in the operation of the Jacquemont machine or any machine of that type. They are:

1. Closing the die
2. Forcing plunger upward
3. Bringing plunger back to casting position
4. Opening die.

The Pack machine has 5 operations instead of the 4 common to this type of machine. They are:

1. Closing the die
2. Forcing plunger upward
3. Bringing plunger back to a position below its casting position (see dotted line L-L′, Fig. 9)
4. Opening the die
5. Returning the plunger to its intermediate or casting position.

Assuming that some metal was forced out below the line II′ (Fig. 8), the second movement of the plunger to the line LL′ would clear any fin that could possibly form and, in operation 4, when the die is opened, this fin is free and is removed with the bulk of the gate. The plunger goes back to its intermediate position II′, only after the die is opened.

In actual operation, this principle has been applied to a large variety of zinc base, cadmium base, aluminum base, magnesium base and copper base alloys without any indication of wear on the plunger or cup. Conditions were deliberately set up to cause "squirting" of the metal past the casting cup, but, in every instance, the resultant fin was removed with the gate and casting.

The proper sequence and timing of the 5 operations of the Pack machine are automatically controlled by positive mechanical means. The operator merely pours the metal into the casting cup and presses a button. The time required for the performance of these 5 operations on a machine that is comparable with a large die casting machine, is about 5 seconds. In the normal operation of a casting machine, the speed of operation is limited by the time required for blowing chips out of the die and for lubricating the die. Speed is also limited by rate of cooling and the ability to supply artificial cooling means. The Pack machine will produce from 2 to 5 shots per minute under normal operation with one operator. With smaller size machines this time can be proportionately reduced. Fig. 9

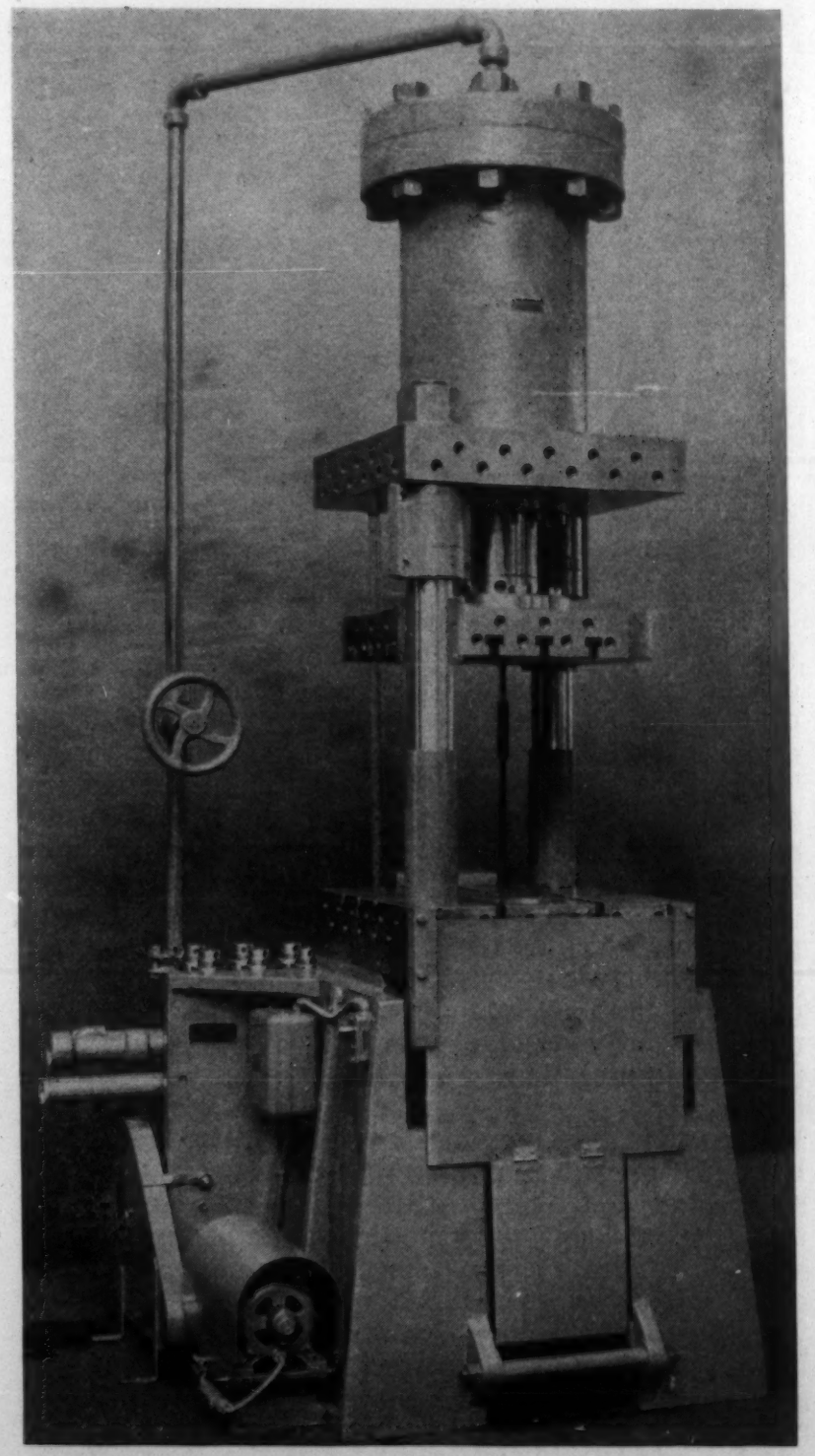


Fig. 9. Pack Type of Press Casting Machine.

shows an assembly view of the Pack machine.

DENSITY OF PRESS CASTINGS

In discussing the density of castings produced by any process, we must differentiate between the basic elements of the process itself and the technique as applied to that process. For example, we know that with a sand mold it is possible to produce sound castings providing the proper gating and other technique is applied. A good experienced foundryman will have no difficulty in producing sound castings.

by the die casting method with a very thin gate because of the pressure available and in a casting of such size and design that small gates are adequate, quite sound die castings are commercially produced by present methods. To produce sound castings of more difficult shapes is, however, a difficult matter. If we aim at sound castings, free from blowholes, we must return to the basic principles that govern the gating of castings in the foundry and permanent mold practice. The first requirement, however, is a machine that can be depended upon to deliver sound, i. e., clean and gas-

Fig. 10. X-Ray Photograph of a Group of Polak Press Castings.

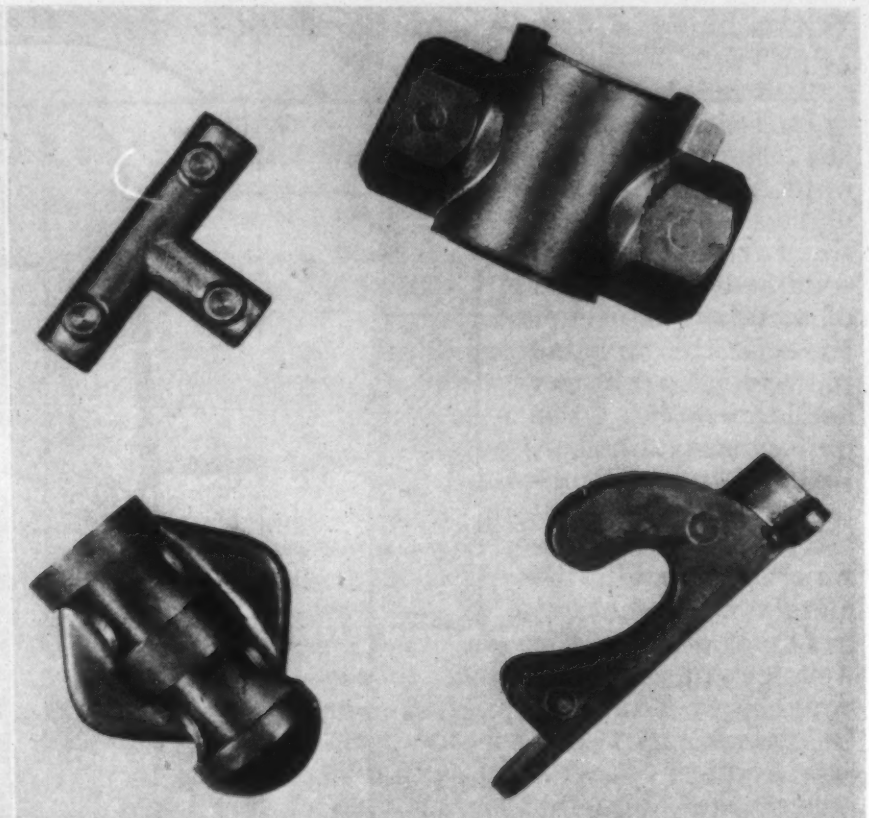


Fig. 11. Actual Photograph of Polak Press Castings shown in Fig. 10.

When we attempt to use a machine for the casting of metals, the first requirement of that machine is that it deliver sound metal into the mold or die. It is self evident that no machine can be said to produce sound castings regardless of the type of gate or vents used. Given, however, a machine that will uniformly deliver sound metal to the die, it is conceivable that a gating and venting technique will be evolved that will ultimately result in the production of dense castings.

The basic objection to the die casting machines in present use which do not deliver the metal from below the surface layer of dross is that they do not deliver uniformly clean and sound metal to the die. This immediately precludes the possibility of producing uniformly sound castings. As a result, the type of gate that can be used in die casting practice is very limited. For example, the user of die castings has generally been able to find some blowholes in his castings, and so an engineer familiar with the art is hesitant about using die castings where the density of the casting is essential. The average die casting manufacturer concentrates on producing a product that will pass visual inspection, or one that will be free from surface blowholes. To do this, he must limit himself to a thin gate since, on a gate of larger cross-section, blowholes may become visible upon the removal of the gate, which would immediately condemn the product. It is possible to produce a casting of a satisfactory appearance free, metal to the die. Certainly, the discharge of metal through a surface layer of dross cannot be expected to deliver sound metal to the die.

Early samples of Polak press castings were quite porous but recent samples of this product that have reached the writer, although not perfect, have been uniformly more solid than the best die castings produced in this country. In Fig. 10, is shown an X-ray photograph of a number of Polak brass castings, chosen at random from samples received here. Actual photographs of these castings are shown in Fig. 11.

The writer's experience in press casting has been obtained mainly with the Pack machine and this experience has demonstrated beyond any question that this machine will deliver uniformly sound metal to the die at all times. It has already been noted that, in order to produce sound castings, we must depart from the standard die casting gating technique. The press casting engineer can control the shape, size and direction of flow of the gate but he cannot control the shape of the casting. He must therefore learn to gate his castings in such a manner as to obtain a minimum of the "squirt" effect and a maximum of density.

In Fig. 12 is shown an X-ray photograph of a set of standard A. S. T. M. die cast test bars; flat, round and square, cast on the Pack machine. The flat test bar is only $^1/_8$" in thickness and, therefore, appears considerably lighter than the heavier square and round test

bars under the X-ray. It will be noted that the metal is fed into these bars from one end and the metal flows the entire length of the bars. These castings are gated through the full cross-section of the bars but although many thousands of these bars were produced from some 50 alloys, they were uniformly free from visible blowholes. It is true that these test bars comprise a rather simple casting but it may be well to remember that no such uniformity was evidenced in the test bars submitted by some of the leading die casting producers in the tests made by the A. S. T. M. In Fig. 13 is shown an

Fig. 12. X-Ray Photograph of a Gate of Standard A. S. T. M. Test Bars Cast on Pack Machine.

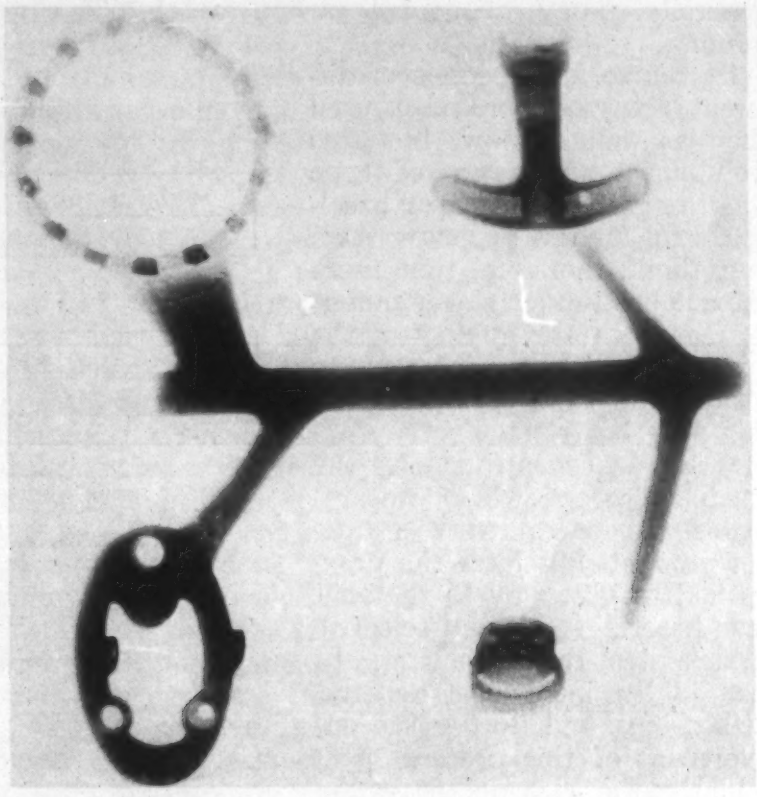
Fig. 13. X-Ray Photograph of a Gate of Castings Made on the Pack Machine.

X-ray photograph of a gate of miscellaneous castings of varying wall thickness, cast with the Pack machine. The variations in wall thickness are indicated by the shading of the parts in the photograph. This X-ray shows quite clearly that the machine is feeding sound metal through the gate. The two lower castings show evidence of blowholes. The lower right hand casting shows clearly that the metal fed to the casting was absolutely sound. It further shows that the metal traveled straight through the center of the casting, but the supply was insufficient to feed the two arms with sufficient rapidity. The photograph shows quite clearly that the inlet to this casting must be increased in thickness and possibly in length.

CONCLUSION

A careful consideration of the foregoing must lead to the conclusion that the casting of metals in metal molds can well be accomplished by the method that has here been termed "Press Casting." The writer is further of the opinion that press casting will find many uses in the metal working arts where die casting cannot be used for the following reasons:

1. Press castings can be produced from any zinc alloy and even pure zinc, whereas the die casting process is limited to those zinc alloys containing aluminum, which tend to be unstable.
2. Press castings can be produced from aluminum alloys and the iron content controlled at will. Commercial aluminum die castings will, unless manufacturing conditions are very carefully controlled, be found to contain upward of 2% iron. High iron, in many instances, is detrimental to the physical properties of the castings.
3. Aluminum press castings can be produced free from the "hard spots" so frequently encountered in aluminum die castings.
4. Press castings may be produced from any of the known alloys of magnesium.
5. Press castings may be produced from copper base alloys, particularly the yellow metals such as the yellow brasses, Muntz metal, manganese bronze and Tobin bronze.
6. Unlimited pressures may be applied in the press casting process which permits of the use of lower casting temperatures



and lower die temperatures with the resultant better physical properties of the castings.

7. Press castings can be produced having a greater density than die castings and there is little doubt that with additional experience it will be possible to produce castings of more uniform soundness than with present die casting methods.
8. It should be possible to build press casting machines to a higher degree of accuracy than present die casting machines and to maintain this accuracy in production since the former are not subjected to thermal strains due to connection with melting furnaces.

In another paper,[4] the writer presented some data on the physical properties of some alloys cast with the Pack machine, described above. Since that paper was written, the writer has arrived at the conclusion that some distinction should be made between this product, the Polak product and the product known to-day as "die castings." In the final analysis, a name is of minor importance. Whether the future pressure casting is called a die casting, a press casting or a permanent mold casting is also of minor importance. The writer has emphasized in this paper some of the outstanding limitations to the use of the product now known as die castings. It will remain for the producers of die casting to bring the quality of their product up to the standard that is in process of being set for press castings or witness the inevitable elimination of the term "die casting" from the metal working arts.

The writer takes this opportunity of expressing his thanks to Mr. W. P. Sherman of Jackson Heights, L. I., Mr. Polak's American representative for the samples and other data pertaining to the Polak machine used in the preparation of this article.

[4] Charles Pack. Die Casting Brass and Other New Alloys *Metal Progress*, Vol. 20, July 1931, pages 72–78, 100.

Recent Progress in Heat Treatment of Ball-Bearing Races**

BY HAAKON STYRI*

IN THE early days of the ball bearing industry the material used for races and balls was a steel of approximately the same analysis as used most generally to-day, about 1% carbon and 1.25% chromium.

Of course, other steels of different analyses were also used then as well as now, but this well-known and approved type was recognized early as an excellent steel for the purpose. One may think, therefore, that there has not been much development in regard to the quality of the material used in the intervening period, and to a certain extent this may be true. Forty years ago the steel was made by the crucible process, which was recognized in general to give a superior product, but later the process had to give way to the acid open-hearth steel and electric furnace steel due, of course, to the rapidly increasing demand for bearings, and during the development of this process, particularly the electric, inferior material was often obtained.

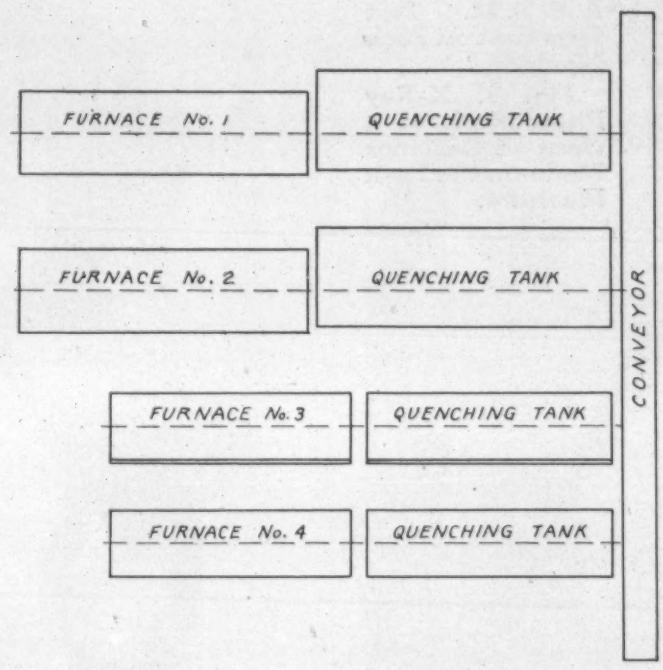


Fig. 1.

A change in the methods of heat treatment from using hand operated furnaces, controlled by the eye, to continuous automatically controlled furnaces followed. This later development has been particularly rapid the last 15 years, during which period various stages of the development have been in use at one or another of the factories of the SKF Industries, Inc., and a brief comparative study both of annealing and hardening methods used at our factories may therefore be of interest.

Annealing. The annealing of forged rings was previously preformed in underfired box type furnaces holding from 5 to 10 tons depending on the type and dimensions of the rings. The underfiring was found to give very uneven annealing. New furnaces were built for overfiring with the combustion chamber over a perforated arch, and the old furnaces were rebuilt for direct overfiring, all with oil as fuel. There was a considerable improvement in uniformity of product, but the furnaces were objectionable because the poor load distribution in the batch type furnaces necessitated slow heating, long holding and slow cooling; and the loading and unloading times were excessive. Car type annealing furnaces were therefore built and equipped with automatic temperature control and oil firing directly overhead. This car type furnace has a working space of $16' \times 4'6'' \times 4'3''$ with $4^1/_2''$ Sil-O-Cel insulation and $4^1/_2''$ fire brick.

These furnaces gave a much more uniform product. The actual annealing cycle was cut to $^1/_6$; the total saving in floor space, for the same production was $^1/_3$, and the saving in total cost per pound of annealed forgings about 15%.

The fuel consumption per pound of steel was, however, about the same as before. In this car type furnace it averaged about 30 gals./ton and for the most efficient loading it is about 25 gals./ton.

Hardening. The hardening of the machined rings at one plant was done from hand operated box-type gas-fired furnaces of conventional design with combustion chamber under the hearth, hand controlled burners and with temperature checked by indicating instruments.

At another plant we had well designed semi-continuous furnaces which were oil fired, with a combustion chamber over a perforated arch. The inside dimensions of the heating chamber proper of these oil fired furnaces were $12' \times 3'4'' \times 2'7''$. The charge was distributed on 4 alloy pans which had cast iron rollers for wheels, running on star shaped rails imbedded on the furnace bottom.

The rings were wired together in different numbers depending on size. The operator would quench from the last pan at the hot end and transfer the pan to the loading end on an overhead monorail when it was emptied.

The capacity of these furnaces was about 500 lbs./hr. and the consumption of fuel oil per hour with a production of 400 lbs./hr. was nearly 9 gallons. The furnace was hand controlled and checked by recorders.

It was found that the hardened material was not sufficiently uniform and, after extensive studies of the details of hardening, a better circulation of oil in the quenching tank was provided and automatic control of the oil burners was installed, whereafter the temperature could be held with a $\pm 5°$ F. variation.

However, these improvements were still not sufficient to satisfy us in regard to uniformity of product. A wide search was made to find if any commercial type of furnace was made for continuous operation that would be satisfactory but we found nothing of suitable design and finally we had a continuous electric roller hearth furnace built for us by an electric furnace company. The furnace which was built for an estimated production of 300 lbs./hr. gave considerable trouble both due to poor arrangement of the heating units and because of mechanical defects, and frequent repairs had to be made. The furnace and quenching tank was continuous; so no handling was necessary between charging end of furnace and discharge end of quenching tank.

The principle of the continuous furnace, of course, proved desirable to facilitate handling, but the trouble experienced with the electric heating made us consider

* SKF Industries, Inc.

** Paper read before the Society of Automotive Engineers at Boston, Sept. 23, 1931.

gas heating for additional furnaces, particularly as a reduction in gas price and calculation of heat losses favored the heating by gas. Maintenance cost was certain to be lower compared with this early electric furnace.

We therefore designed and built roller hearth type furnaces for gas heating for a production of 300 lbs./hr. and later more furnaces for 500 lbs./hr. and we also changed over the electric furnace to gas heating in order to have only one system in the shop for production hardening.

The large furnaces were provided with 3 control zones, the 300 lb. furnace with 2.

The general arrangement of furnaces and tanks is shown in Fig. 1. There are conveyors in the quenching tanks which deposit the rings on another belt conveyor that takes the rings to a washing machine.

The operating data are given in Table I and the furnace dimensions in Table II.

The energy loss for holding with empty furnace is measured for uniform temperature inside, which explains the low additional amount for full load condition, where the extra energy for the electric furnace is less than theoretical. The explanation is that when the furnace is in continuous operation there is a gradual increase in temperature from charging end to half way to the discharge end and therefore less heat loss than when held at uniform temperature.

Running the 500 pound gas furnace under this condition empty needed only about 260 ft.^{3}/hr. instead of 530.

Table I

	lbs./hr.	Heating up from cold	Holding at 840° C. (1544° F.)	Full load	Total incl. heating and idling ft.^{3}/lb.	Relative total cost/lb.
Box type furnace	32.2				29	2
Oil fired furnace	360					1
Electric furnace	300	160 kw. hr.	23.5 kw. hr.	42 kw.		
Electric furnace changed to gas	300	4400 ft.^{3}	310 ft.^{3}/hr.	480 ft.^{3}/hr.	3	0.9
Large gas furnace	500	7400 ft.^{3}	530 ft.^{3}/hr.	800 ft.^{3}/hr.	3	0.9

Table II

Furnace No.	Firebrick thickness	Insulation thickness	Furnace chamber Length	Width	Height
1	4 1/2	8″	14′ 3″	2′ 1″	1′ 7″
4	4 1/2	7 1/2	10′ 8 1/2″	1′ 5″	1′ 6 1/4″
Old elec. furnace now No. 4	2 1/2	10 1/2	10′ 8 1/2″	1′ 3″	1′ 9 1/2″

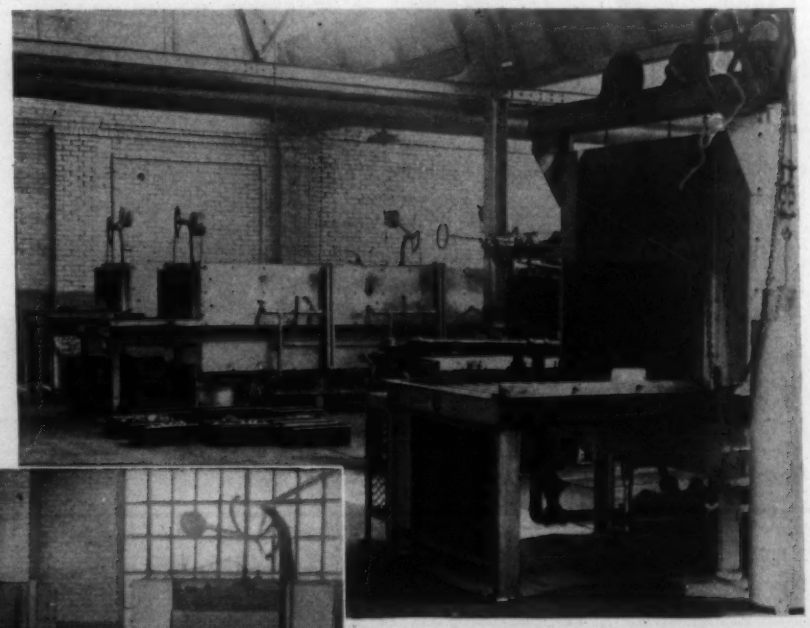
The furnaces are equipped with automatic gas mixers and automatic recording temperature control.

If the furnaces had been designed for oil firing a saving in the fuel bill would have been obtained but at greater cost for construction and maintenance and with less satisfactory operating conditions due to soot and oil leaks.

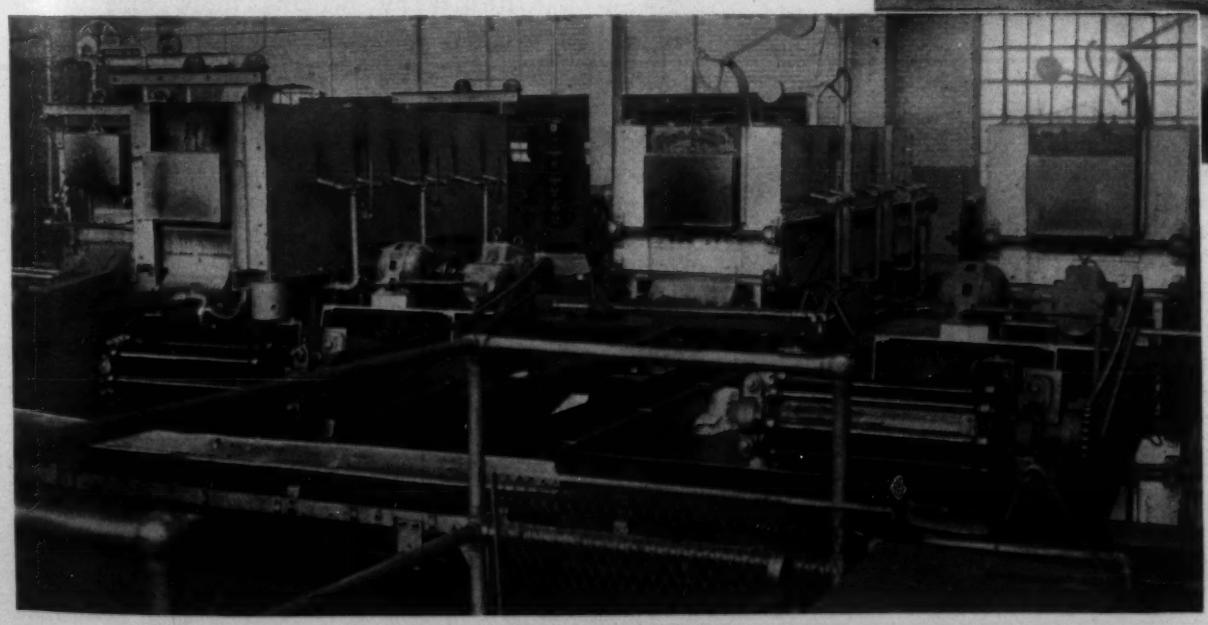
Cost. The overhead charges have increased with installation of more expensive equipment, and therefore the total cost for hardening has not decreased much for the automatic furnaces over the oil-fired semi-automatic but there is a considerable saving over the old batch type furnaces. The present capacity is much greater and the layout much more convenient; so the cost figures should improve with increased production.

In connection with the change over of hardening equipment we have also introduced magnetic testing to replace the earlier hardness testing by scleroscope and have thereby been able to test for hardness directly after heat treatment and before grinding, so that it is possible to rectify most of the faulty hardening if it should occur. This was not possible when the rings had to be ground before testing. The present scrap due to hardening is less than .02%.

Conclusion. While the direct economic advantages in the new methods for heat treatment are not so very striking in cost per pound, except compared with the oldest batch type hardening furnaces, the greater independence of the operation from the human element, and the better control, have vastly improved the operating conditions, and have given us a much more uniform product which have been of considerable benefit in the subsequent manufacturing operations and, lastly, which perhaps is most important, have improved the product to such an extent that the estimated endurance of new bearings compared with those of ten years ago is about 3 times higher.



(Above) Charging ends of the furnaces.



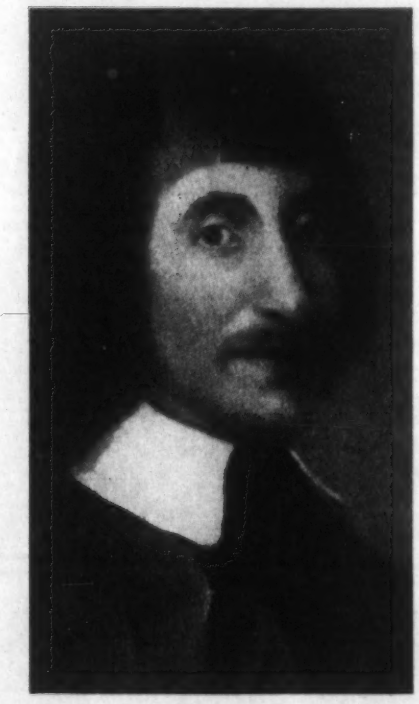
(Left) Discharge end and conveyor systems of the battery of automatic production furnaces.

Early Chemistry and Chemists in the Iron and Steel Industries of America

BY L. W. SPRING AND L. E. GILMORE*

Sauntering the Streets of One Hundred Years Ago

WERE it possible for us to set the clock back a hundred years and translate ourselves thence, with what interest would we stroll along the streets of the towns of our forebears, noting the latter, their habits, their shops, factories, and homes? How did our great grandparents and others of those days look and act—a hundred years ago? Even if we were not permitted to speak with them, the remainder of the experience would be of extreme interest, would it not? Likewise our predecessors in the iron and steel industries: Who were they? What are the conditions under which they labored? Can we in some way see them "on location?" This, too, would prove interesting.



John Winthrop, Jr.

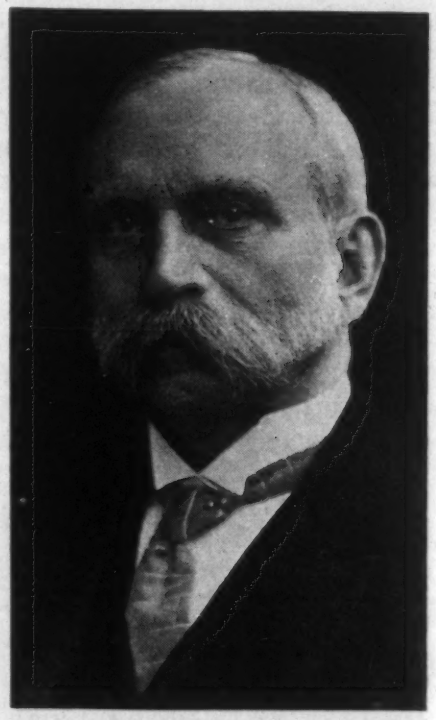
When was chemistry first applied to iron and steel making, anyway? Who was the first steel chemist and where?

This, admittedly, is a rather late date to ask or try to answer such a question, for many of those who could and would have given us the answers have passed away. Even during the past thirty—yes—twenty years we have largely failed to talk of the "old" times with men who had lived them. Now it is too late for some of it. We have let the evidence slip.

Search for Historical Data

However, the Chicago section of the American Chemical Society together with the Chicago Chemists Club three years ago appointed a committee to collect for later publication as much as can be learned at this rather late date in regard to early chemistry in the Chicago district. Concerning the chemist and his advent into the iron and steel mills, blast furnaces and foundries of the United States, the authors have data which has been accumulating for many years. This information will be presented in a short series of articles in METALS & ALLOYS.

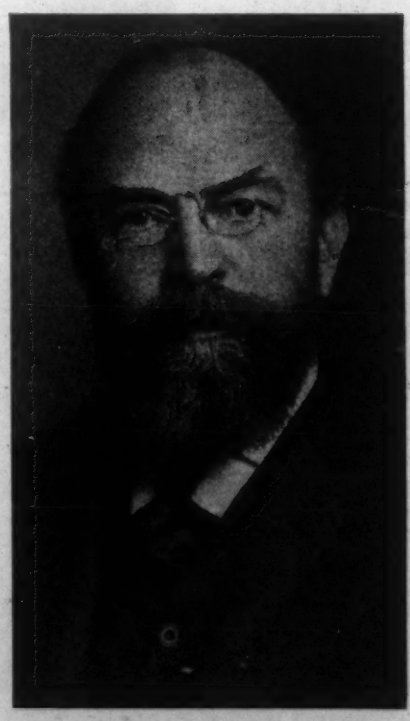
The difficulty of discovering and verifying information about men and incidents of bygone days may be imagined. Needless to say, the information so far obtained is far from complete; yes, it is even fragmentary and errors may creep in. For correction of the latter we ask that proper information be sent to the editor of METALS & ALLOYS. Also, there will be some who read these articles who have or can give definite and more extended information than has come to us. It will be considered a favor and aid to a good cause if such will write giving all possible data or advising who can give it. We wish here to acknowledge our indebtedness to the hundreds who have contributed information—some of it years ago.



Prof. Chas. F. Chandler

When Did Chemistry Become Steel Chemistry?

The beginnings of chemistry in the steel business is masked in obscurity. This is quite natural because this, like other such beginnings was quite indefinite. Begun in a small way and with no one to herald the applications of chemistry, they are like Topsy—they just "grew"—and for awhile grew so intangibly as to be quite unnoticed and, therefore, are more or less unavailable for historical purposes.



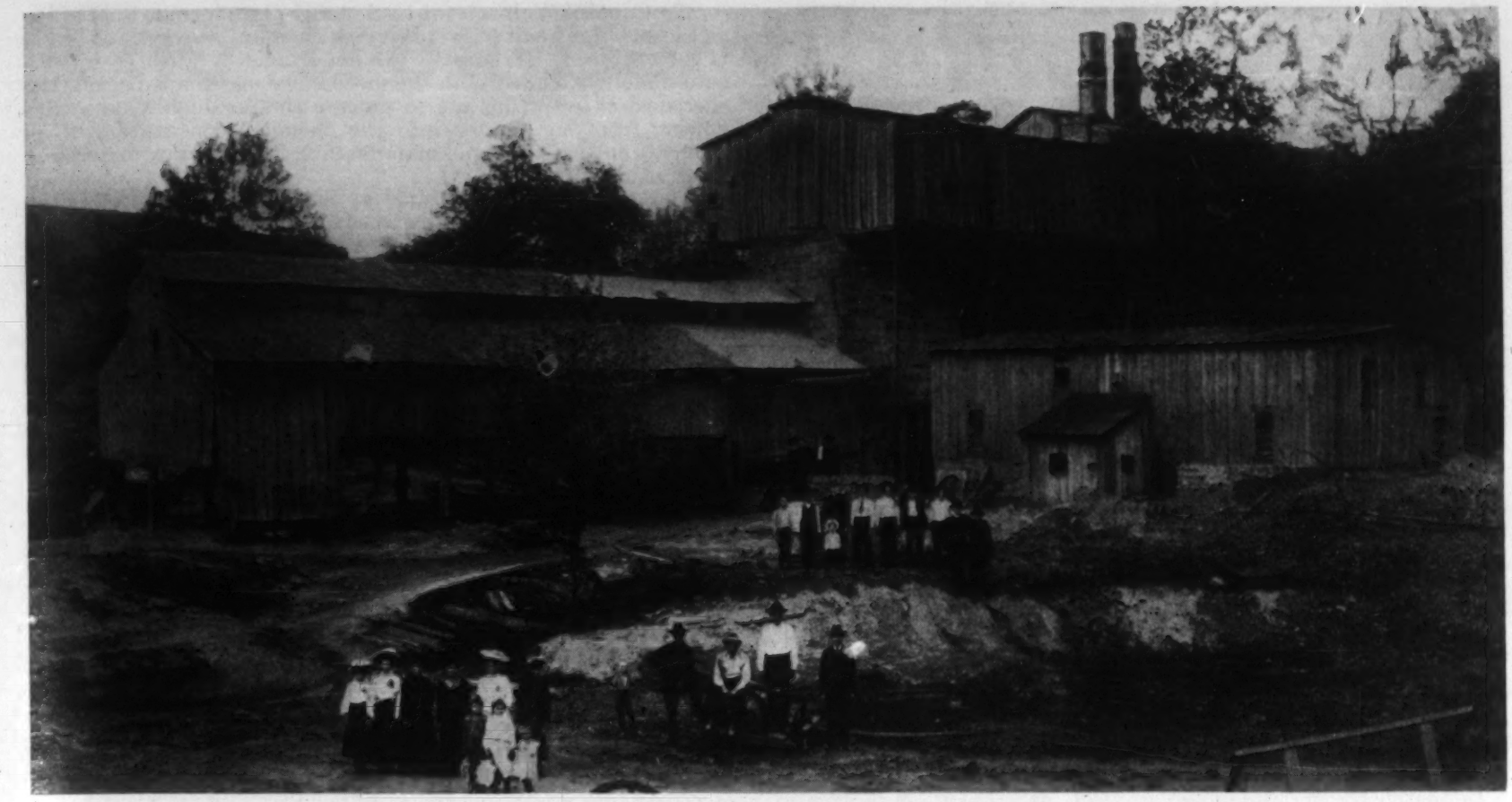
Prof. N. W. Lord

Chemistry as a science is a descendant of alchemy of the Middle Ages.

Chemistry became more and more scientific and virile through the work of Paracelsus, Becher, Stahl, Scheele, Dalton, Berzelius, Avogadro and hundreds of others. Of course, the existence of carbon, sulphur, phosphorus, silicon and manganese was known and many of the habits of these elements had been ascertained before they were recognized as the big five of early iron and steel. Therefore, we can hardly call the discoverers of these, or other elements later found to be important in the steel industry, steel chemists or metallurgists, though they contributed much.

In this connection a quotation from "Iron and Carbon Mechanically Considered" by John. B. Pearse in Vol. 4, Transactions of the A. I. M. E., 1875, is pertinent:

* Crane Company.



Bloom Furnace located in Section 30, Bloom Township, Scioto County, Ohio, built 1832 by John Benner and others; abandoned, about 1910. Dimensions 33 x 11 feet; capacity 8 tons per day; ores used, local, Ferriferous, Big Red Block, Little Red Block and Boggs. Fuel, charcoal; limestone, local, Vanport. Iron hauled to Ohio River at Sciotoville, 14 miles, until opening of Scioto and Hocking Valley Railroad in 1853, then loaded at Bloom Switch.

Photo taken while furnace was in active operation. This was one of the last of the old charcoal iron furnaces to go out of commission. Hitherto unpublished photo, Courtesy of Wilber Stout, State Geologist, Columbus, Ohio.

"Seeing, then, that carbon is such an important element in iron it is needless to say that the history of its determination has been a most interesting one. It began practically with Berzelius, who laid a wonderfully good foundation in this matter, as he did in so many others in chemistry. But Karsten was the first to apply the processes, suggested previous to his time systematically to the analysis of iron, discovering among other things the true nature of graphite. He did wonderful work with a process (chloride of silver) that required ten to twenty days for a single estimation. Imagine, if you please, the despair of a modern chemist under such circumstances at a works temporarily making bad steel." (Many chemists make carbon determinations in five minutes now.)

Mushet, of course, recognized that manganese was necessary to the success of the Bessemer steel process. His patent for the addition of manganese-containing spiegeleisen, so necessary to the success of the converter process, was taken out in 1856. This, of course, was a direct application of chemistry and metallurgy to steel making.

Other than the influence of carbon on mild steel as made by Bessemer's process in England and the independently invented Kelly process in America, the deleterious influence of phosphorus apparently was learned by Bessemer through selling to several sheet makers of Great Britain licenses to use his newly invented process. His licensees failed of success due to their use of high phosphorous pig iron. Bessemer fortunately (though it was accidental) had used iron of low phosphorous content in his experiments.

Therefore, early steel chemistry in the United States concerned itself mainly with carbon content of the steel, with the phosphorus in the ores used for pig iron for steel making, and, further, of course, with the iron content of the ores. On these two latter elements the value of the ore mainly was determined, with silica or fluxing quality, another but less well-known consideration.

In a recent interesting account,[1] John Winthrop, Jr. "is generally credited with being the first chemist and metallurgist in the American colonies, and this we note, was supplemented with a knowledge of alchemy. Again, his practical knowledge of chemistry gave him many opportunities to develop mining and engineering industries for the economic progress of the colony and of the mother country, and evidence of his skill is still to be seen in parts of Connecticut. These various engineering developments *led to his promoting the pursuit of iron melting and foundry business about 1642. He also promoted many chemical* industries, for we note that in 1648 Winthrop was granted a commission by the Court of Massachusetts to manufacture salt and saltpeter. Later, in 1651, in Connecticut, he was granted a monopoly for working lead, copper, tin, antimony, vitriol, alum and other like industries."

As to analytical chemistry the state geologists kept careful records of the mineral resources of their respective states. A letter from the Geological Survey of Ohio (Wilbur Stout, present State Geologist) for instance, indicates one connection between chemistry and the steel industry.

The Geological Survey Aids by Chemistry Work for the Early Metallurgical Industries of Ohio

"In Ohio the iron industry began with the founding of Hopewell furnace in 1804 near Poland in Mahoning County and was projected into southern Ohio when Brush Creek furnace began operations in 1812 on Brush Creek in Adams County. The business developed rapidly and nearly fifty charcoal furnaces were built before 1845, when coal began to replace charcoal as a fuel and when furnace construction increased to larger capacities. The charcoal furnaces during this period (1804-1845) were all small and were operated by observation as to the proper burden. Little chemical work was done either by the furnace people or by outside interests. In the records of the Geological Survey of Ohio, Second Annual Report 1828, only two analyses are given and these are only partial ones.[2]

---

[1] Frederick E. Brasch. The Royal Society of London and Its Influence Upon Scientific Thought in the American Colonies. *Scientific Monthly*, Oct. 1931.

[2] Ore Analyses Given in Second Annual Report 1838, Geological Survey of Ohio.

"Assay of iron, ore below Buhr stone near Radcliffe, Jackson County Ohio.

Iron	58.626%
Oxygen, combined	24.802%
Water hygrometric and combined	13.250%
Earthy matter	1.508%
Loss	1.814%
	100.000%

'Big Ben' on Mr. James Rodgers tract near Jackson furnace.

Oxide of Iron composed of	Iron	48.75%
	Oxygen	20.89%
	Water of combination	12.79%
Hygrometric water		0.31%
Earthy matter fixed		16.15%
Loss, a part of which is probably sulphuret of zinc		1.11%
		100.00%"

The second period of the iron industry may be considered as that from 1845 to 1870, by which date coke instead of coal had become the best known fuel for smelting, and lake ores had practically replaced the local supplies. These changes brought larger outputs, more refinement in selection of raw materials, and greater care in balancing the burdens. As before, however, the metallurgical work from 1845 to 1870 appears to have been accomplished without definite control by the chemist.

In the iron industry after 1870 the conditions appear to have changed so that the chemist became a factor in a more definite way. This is reflected also in the work of the Geological Survey of Ohio which in 1869 appointed T. G. Wormley as the staff chemist. The Report of Progress for 1870 gives analyses of many samples of iron ore from Perry, Hocking, Holmes, Tuscarawas, Columbiana and other counties. These samples were collected mainly at mines operated by the furnace companies and the analyses were distributed to those interested.

In the next report published in 1871 many analyses of ores from Perry, Hocking, Vinton, Jackson, Scioto, Lawrence, Washington and Athens counties were given from samples collected by the Geological Survey or from those sent in by the furnace operators. In this report the methods of analyses also are given in detail. At this time, 1871, the chief chemist, Theodore G. Wormley, had two assistants, Leo Mees and Henry Weber, the latter becoming head of the Department of Agricultural Chemistry at Ohio State University. These chemical results were transmitted to the furnace managers who undoubtedly made use of them in the selection of ores and limestones and in furnace control. Such chemical work was continued, as is shown in volumes issued in 1873, 1874 and 1878. In the report of 1874 tests were given in iron ores from Columbiana, Holmes, Jefferson and Tuscarawas counties and from the Hanging Rock, Hocking Valley and Sunday Creek districts.

From 1889 to 1899, N. W. Lord, who later became head of the department of Metallurgy at Ohio State University, was chief chemist of the Geological Survey and did much work on iron ores, cokes, limestones, slags and pig iron. His assistant was Willis J. Root, who later became superintendent of the Columbus Works of the Carnegie Steel Company. In the report of 1884 N. W. Lord wrote a chapter on the Iron Manufacture of Ohio which gives in detail much information on furnace charges and operations. Other chemists mentioned in the report are Chauvenet, Blair, Loomis, Professor Dudley, Gill, W. D. Wood and J. K. Shinn."

It is thus evident that before the days of the regular blast furnace chemist, much detailed information concerning the composition of the raw materials and that of the end products was available to the managers and foundrymen. Much of this came through the geological surveys and through the chemical departments of the universities. In a rough way furnace men also measured the richness of the ores by the quantity or weight required to make a ton of iron. The purity of the limestone was judged by the texture and the fracture which relatively are fairly safe guides. On the whole, the data available to the industry appears to have been sufficient for the successful operation of the old charcoal and coal furnace.

Chemistry Applied to Manufacture of Cast Iron Cannon

Following up the gradual spread of chemical knowledge in iron and steel plants from another angle, we go back again to Pearse's article on "Iron and Carbon Mechanically Considered." Pearse recounts what was probably the earliest attempt in this country, at least systematically and exhaustively, to correlate chemistry with the quality of an iron product:

"To Captain Walbach (of U. S. Army Ordnance) is due, so far as I know, the credit of first bringing chemical research to the aid of the engineer. He foresaw the importance of a field of investigation more extended than the mechanical one and it became the cherished object of his life to procure the invaluable knowledge flowing from an inquiry into the chemical constitution of all elements entering into gun manufacture, from the raw material to the finished product.

A laboratory was established at Pikesville Arsenal in 1849 in charge of Messrs. Morfit and James C. Booth under general direction of Capt. Walbach. Their chemical work continued with some interruption for nearly six years, covering a field which, though not untrodden, had never been explored with critical accuracy. After making some thousand determinations to compare process and insure accuracy, Messrs. Morfit and Booth embodied their results in a final report in 1855, which contained the complete analyses of the cast iron of 32 guns, fully described by Capt. Walbach. This report embodied a complete system of iron analysis, perfect for the time, and is still an authority on many elements."

Introducing More Early Iron and Steel Chemists

Dr. James C. Booth, mentioned in the account above, had in 1836 established the laboratory which later became Booth, Garrett & Blair of Philadelphia. Dr. Otto Wuth and S. G. Stafford had a commercial laboratory in Pittsburgh in 1865 and later. Wuth had been with Bunsen in Heidelberg before he came to the United States in 1862.

Another chemist of these very early days before the iron and steel industry had need or rather had a sense of need of a chemist might be mentioned: Prof. Charles F. Chandler of Columbia University. He is sometimes called the dean of chemists in the United States. He was the first chemist for New York City about 1852. It was he who urged the use of and necessity for vents in household plumbing. The Wall Paper Arsenic Scare also was brought to him as consulting chemist.

Of course one thing led to another. The foundation stones were being laid for the introduction of chemists in the iron and steel industry. In 1860 Robert W. Hunt, after taking a course in analytical chemistry in the laboratory of Booth, Garrett & Blair, established the first laboratory in an iron or steel plant in the United States. More will be said in a later article in this connection. While the first laboratory in an iron or steel plant was established in 1860 at Cambria and another at Wyandotte in 1863, it was probably not until 1867, with the advent of T. T. Morrell at Cambria, that their laboratory was on a fairly steady schedule of operation.

O. D. Allen was at Freedom Iron Works, Logan, Pa. (now Burnham, Pa.) in 1869. In 1870 Andrew McCreath established the Pennsylvania Steel Co. laboratory which has operated continuously ever since. In 1872, Charles A. Brinley established the laboratory at Midvale. In 1872 we also find J. H. Cramer chemist at North Chicago Rolling Mill Co. and Frederick A. Emmerton at the Joliet Works of Illinois Steel Co.

Naturally the blast furnace began to utilize the services of the chemist to control the quality of their product. About 1870 Dr. Fricke was engaged as chemist at the Lucy furnace owned by the Carnegie group with great benefit to the company as will be shown in a later article.

Therefore by 1872 the chemist was rather firmly established in the iron and steel industry and more and more plants were finding the services of a chemist necessary.

◆ ◆ ◆

Buffalo was selected for the fourteenth annual National Metal Congress and Exposition at a Meeting of the Board of Directors of the American Society for Steel Treating in Cleveland, February 5th. The week of October 3, 1932 was chosen as the date.

The Exposition and technical sessions of the Congress will be held at the 174th Regimental Armory. This will be the first year that the National Metal Congress and Exposition has been held in Buffalo.

The Iron-Beryllium System

BY R. H. HARRINGTON*

BERYLLIUM to-day occupies a position on the market similar to that of aluminum of some years ago. Though beryllium ores are relatively common, the cost of recovery is so high that a large demand must arise before the market price of the metal will be lowered to a reasonable figure. Research concerning this element and its alloys has been recently intensified, partly for the object of finding some specialized use that would provide a greater demand for the metal.

During the course of some recent work it became of interest to study the alloys of beryllium with iron. The most complete phase diagram for the Fe-Be system appears to be that of G. Oesterheld, published in the *Zeitschrift für anorganische Chemie* for 1916. This is shown in Fig. 1. The marked similarity to the iron-carbon system is at once noticeable. It is curious that the line AB, apparently marking a eutectoid inversion, has not been continued to the left of the eutectoid composition of 4.8% beryllium. In the *Zeitschrift für Technische Physik* for 1929, F. Wever published a section of an iron-beryllium diagram, showing a small γ-field, closed at about 0.50% Be. The data for this diagram were published by F. Wever and A. Müller in *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung* in 1929. Their data were obtained from alloys containing less than 2% Be and do not show any indication of a eutectoid. There are, then, wide discrepancies between the 2 diagrams. Oesterheld's work covers a wide range of alloys and gives considerable evidence of the formation of a eutectoid. Wever's work, confined to very low beryllium alloys, was probably done on alloys of greater purity and with, perhaps, the greater precision that accompanied the general advance of this science in the past dozen years.

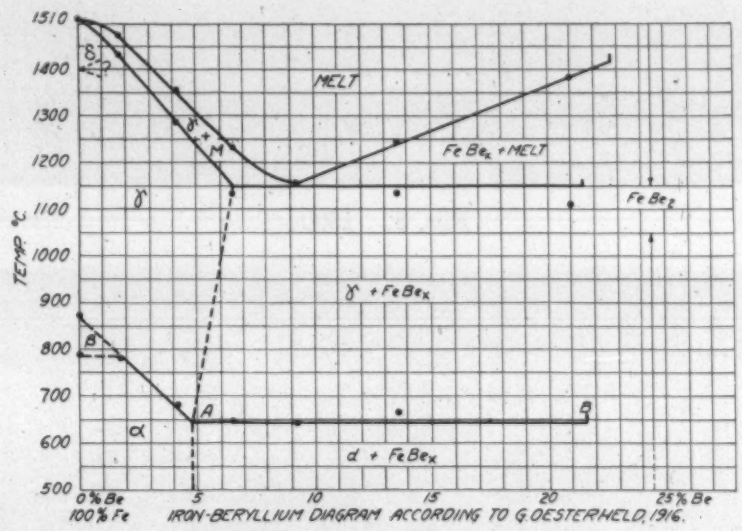


Fig. 1.

There are several simple experiments that may be made to quickly yield qualitative information concerning diagrams that appear to be open to question. In the present instance the action of powdered beryllium on iron at a temperature within the range of the γ-field was found to be similar to that of aluminum in pack calorizing of iron and steel. It was, therefore, possible to develop a process of pack "berylizing" similar to that of pack calorizing.

A cylindrical sample of cold rolled steel, 1 inch long and $^5/_{16}$ inch in diameter, was packed in a small tube with a powdered mixture consisting of 40% of powdered beryllium and 60% of alumina. The packed tube was heated for 6 hours at 1000° C. in an atmosphere of hydrogen. After cooling in the furnace, the sample was removed and examined. There was a thin surface layer, quite adherent, that resisted saw-cutting and filing. The sample was sectioned, polished and etched with nital.

Fig. 2 shows the structure, at a magnification of 200×, of the sample as furnace cooled from the berylizing temperature.

* Research metallurgist, General Electric Co., Schenectady, N. Y.

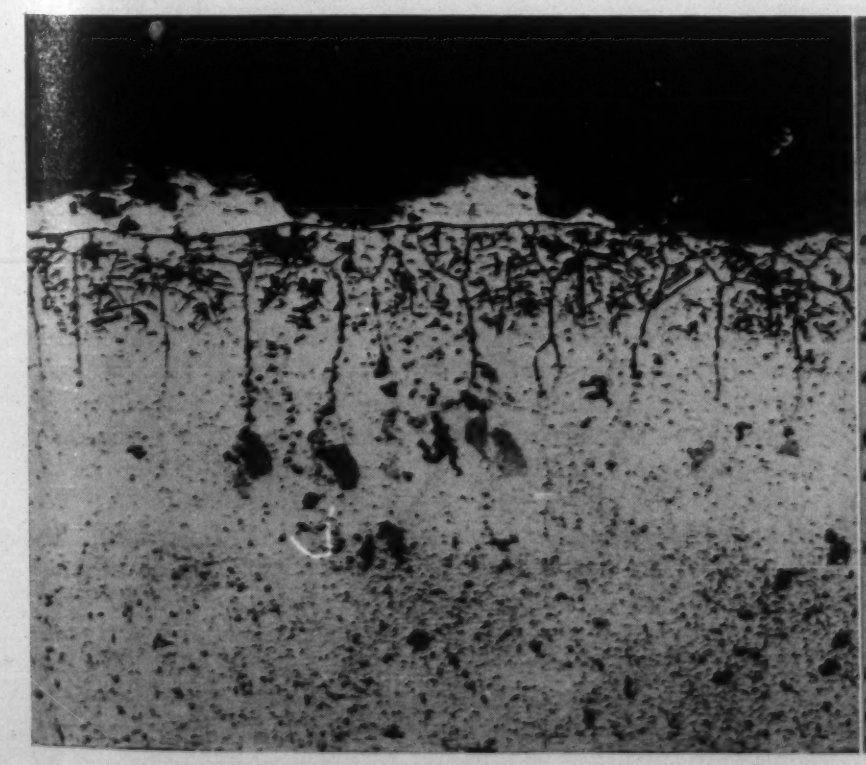


Fig. 2. 200×.

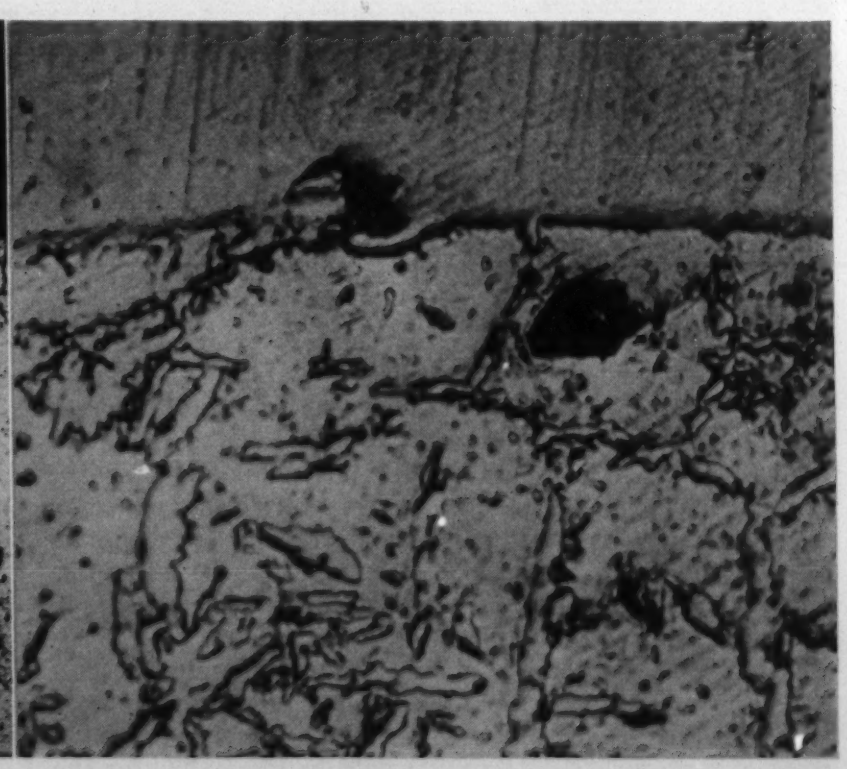


Fig. 3. 1500 ×.

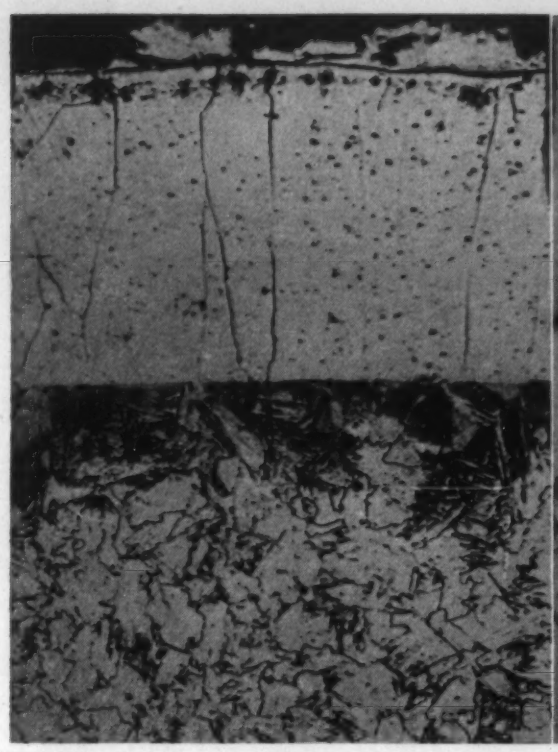


Fig. 4. 200×.

Fig. 5. 1500×.

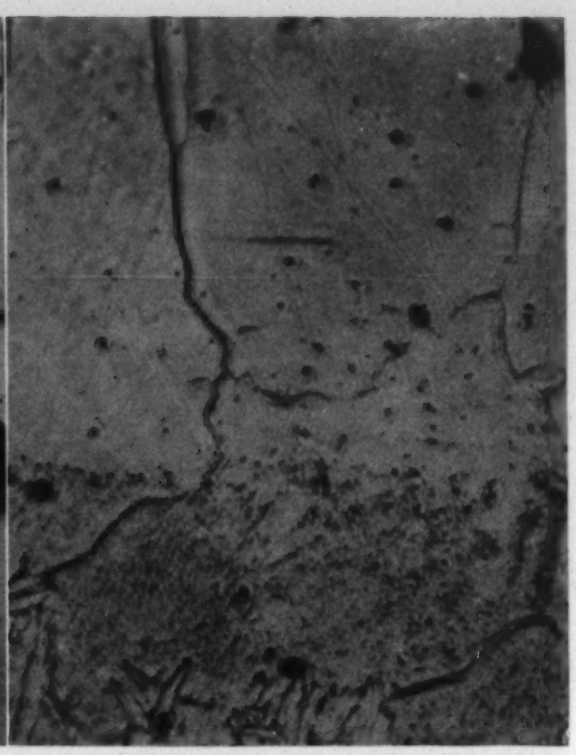


Fig. 6. 1500×.

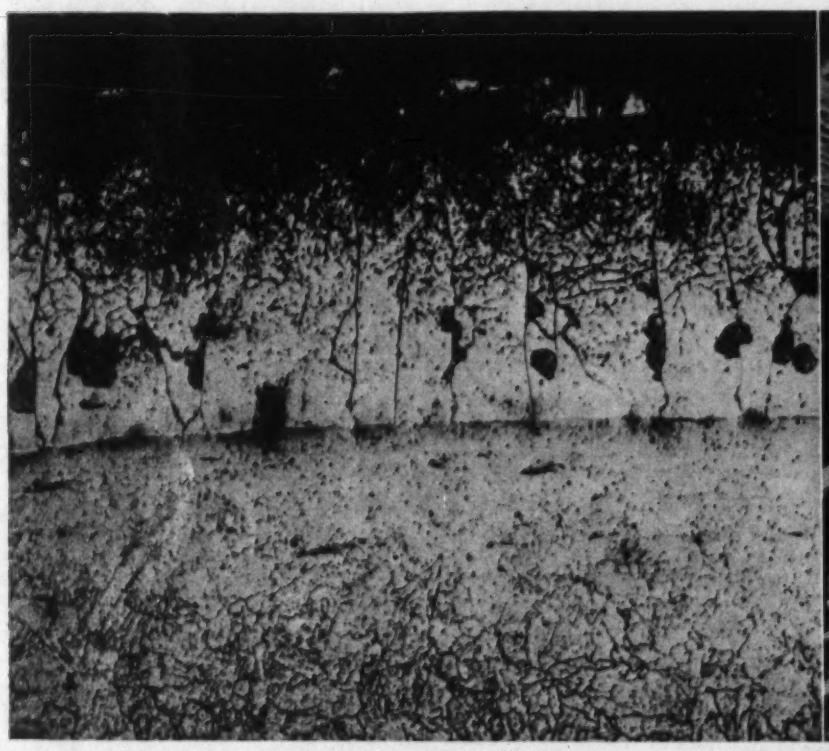


Fig. 7. 200×.

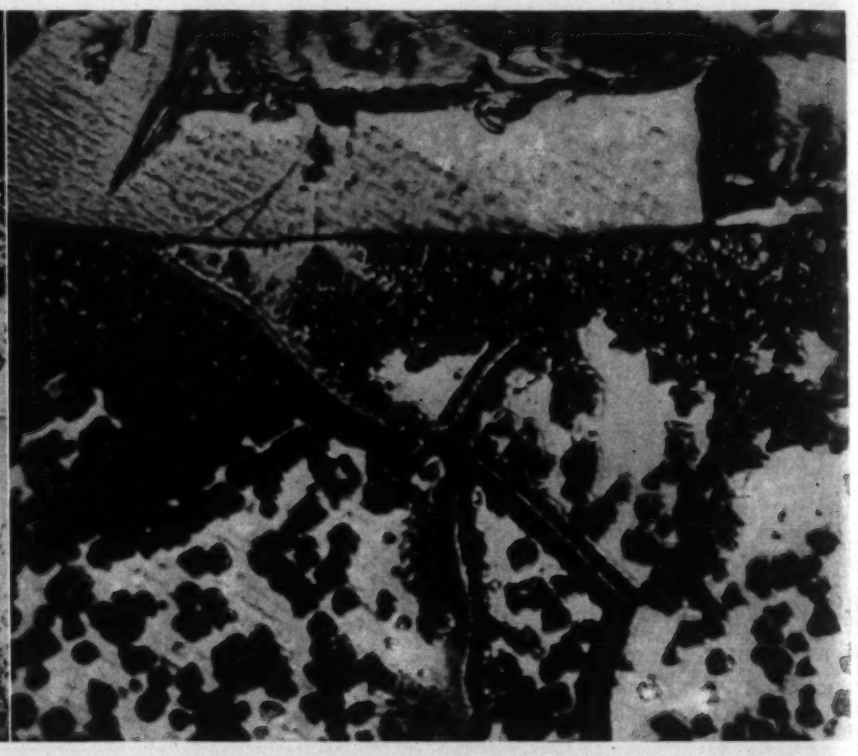


Fig. 8. 1500×.

Fig. 3 shows the high beryllium edge of the case at a magnification of 1500×. Examination of Fig. 2 indicates the presence of a thin case of hard, structureless material. This material appears to behave like a compound and to have properties characteristic of a compound. Inside of this compound layer is a diffusion zone of about 10 mils depth. Long columnar grains, typical of diffusion reactions, extend nearly through this zone. The boundaries of these columnar grains are filled with the compound that constitutes the case. These compound streamers narrow as they penetrate the diffusion zone and end about $^3/_4$ of the way through it. In the columnar grains and near the junction with the compound case the compound has precipitated in the form of needles or platelets. This precipitate dwindles and disappears near the center of the diffusion zone. The carbon of the cold rolled steel sample appears to have been removed by the hydrogen to a depth about equal to twice that of the diffusion zone.

Except for the absence of a eutectic zone this sample seems to be described by Oesterheld's diagram. Since the temperature of the berylizing action was 150° C. below the melting point of Oesterheld's eutectic it would be impossible for the eutectic to form. Let us assume, then, that Oesterheld's diagram may be applied to this sample. The thin, hard and somewhat brittle case may be the compound $FeBe_2$ and the diffusion zone grades from nearly eutectic composition in to 0% Be. The rate of cooling in the hydrogen furnace appears to have been too fast for the formation of the eutectoid and the precipitated compound has formed in needles not unlike a Widmanstätten structure.

The same sample was then heated to 1000° C., quenched in caustic, repolished and etched. Fig. 4 shows the case and diffusion zone of the quenched sample at 200× magnification. Fig. 5 shows the case and outer edge of the diffusion zone at a magnification of 1500×. Fig. 6 shows the inner edge of the diffusion zone and a part of the unberylized sample. The compound case appears unchanged. All of the percipitated compound has been retained in solid solution in the diffusion zone. There is some evidence of 2 systems of boundaries. Some carbon from the core of the sample has migrated toward the inner edge of the beryllium diffusion zone.

It might be expected that the solid solution, retained by the quench, would yield a dispersed precipitate when drawn at 600° C., just below the eutectoid temperature indicated by Oesterheld. Fig. 7 is a 200× magnification of the same

Fig. 9. 1500×.

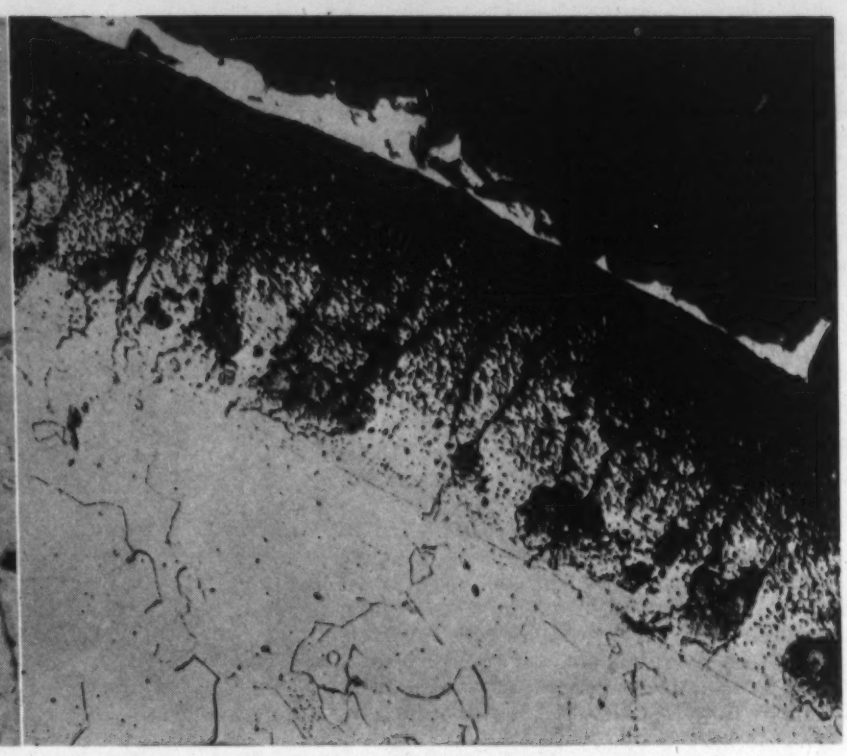


Fig. 10. 200×.

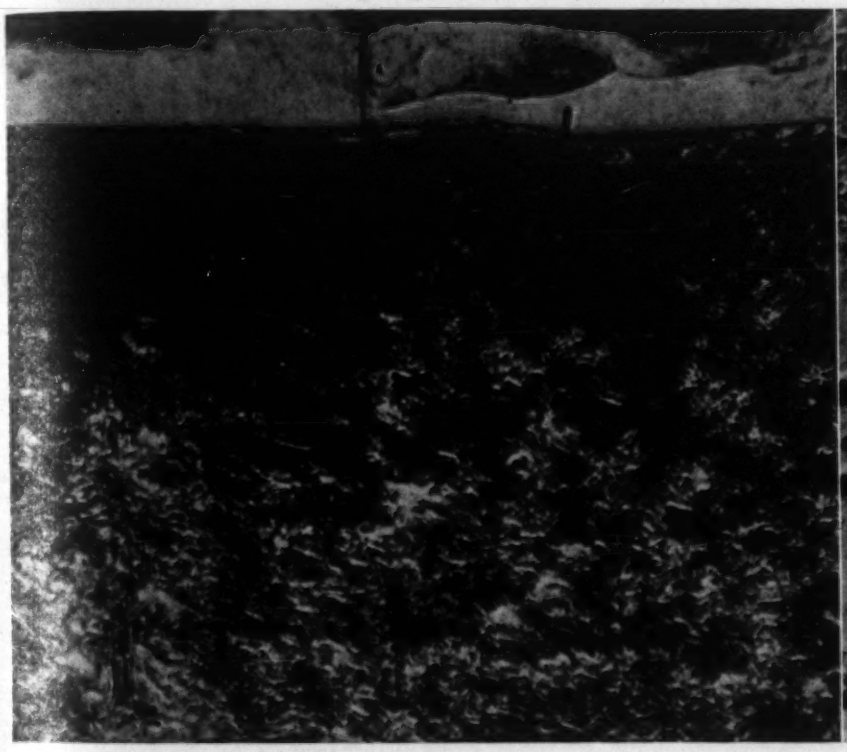


Fig. 11. 1500 ×.

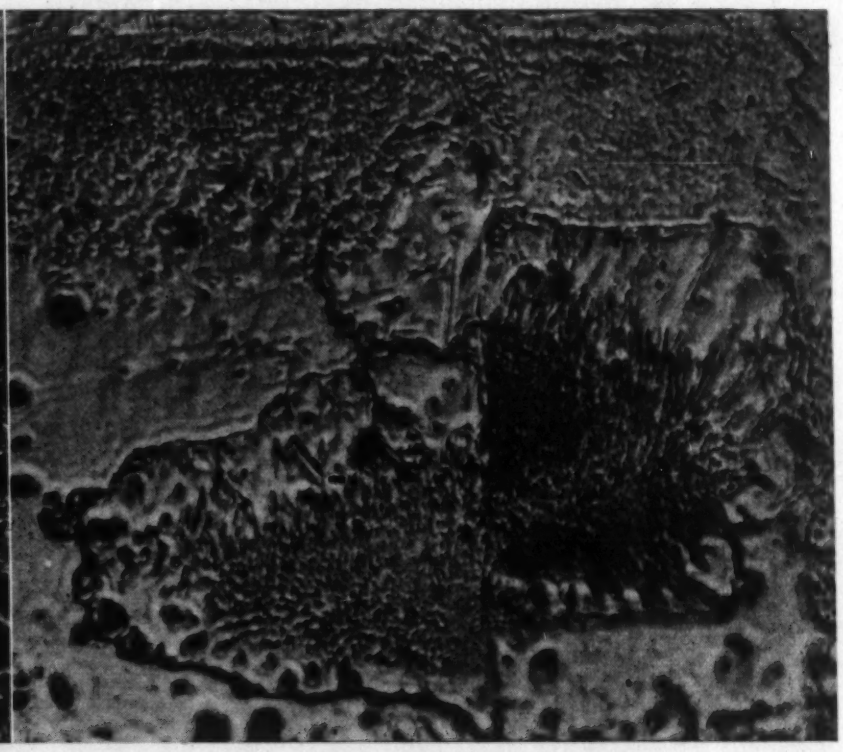


Fig. 12. 1500×.

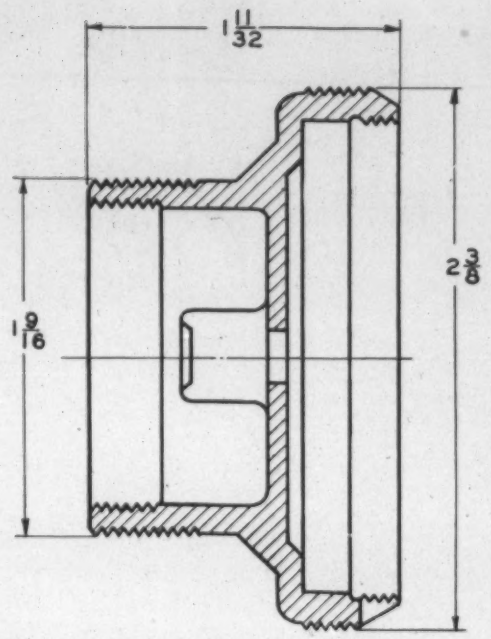
sample after a 600° C. draw. Fig. 8 is a 1500× magnification of the case and part of the diffusion zone. The compound has again precipitated in the boundaries of the solution grains and is also dispersed through the grains in small particles. It appears as if the section, close to the compound case, might be nearly of eutectic composition. Fig. 9 shows a section of the low beryllium part of the diffusion zone. Apparently the temperature of the draw was close enough to the eutectoid temperature to allow of some segregation into areas that resemble pearlite in steel. These areas usually form with one side in contact with the compound precipitated in the boundaries of the large solution grains. The structure of these areas resembles that of granular pearlite or sorbite.

The sample was then annealed at 700° C., a temperature about 50° C. above the eutectoid temperature indicated by Oesterheld. Fig. 10 shows the berylized zone at a magnification of 200×. The precipitation of the compound is more complete and the eutectoid-like areas have grown considerably. Fig. 11 shows a section of the diffusion zone bounded by the compound case and is of 1500× magnification. There seems to be a tendency toward a lamellar structure. Fig. 12, at 1500× magnification, shows some small eutectoid-like areas right at the inner boundary of the diffusion zone. The structure of these areas shows a lamellar tendency. This also seems to indicate a rather low solubility of the compound in the annealed material. Thus, it seems that the eutectoid line, AB, in Oesterheld's diagram should be continued to a low Be content similar to the pearlite or A_1 line of the Fe-C system.

Qualitatively, these results appear to check the work of Oesterheld. Since it is very difficult to obtain pure beryllium, it may be that the differences in the phase-diagrams of Oesterheld and Wever will sometime be traced to the presence of some impurity in the alloys used by one or the other. If some specific alloy of iron and beryllium should prove to be of outstanding value it would become necessary to check the phase diagram in quantitative detail. It is also the purpose of this work to show the qualitative value of studying a sample showing a wide-ranged but uniformly occurring composition gradient as a means of checking phase diagrams. Repeated runs made with the berylizing mixture yielded similar structural results.†

† The writer's personal thanks are due to Mr. G. R Brophy for advice as to the berylizing process and to Mr L. L. Wyman for the photomicrographs.

It will be noted from the above table that the composition limits of both aluminum die casting alloys are somewhat closer than those adopted by Committee B-6 of the American Society for Testing Materials and published as Tentative Standard B85–31T. However, the most significant thing about the Western Electric Specification is that the composition limits represent actual limiting percentages for acceptance of parts and do not simply form the basis for negotiations between the customer and manufacturer as to the usability of outside limit material. While this uniformity of composition necessitates careful supervision at all points, it has been demonstrated to be practical in a department producing many millions of parts annually.



Although the limit for iron is placed at 2% in alloy No. 8, it has been demonstrated that the iron can be maintained under 1% with goose-neck, air operated die casting machines, if necessary. However, practical considerations, principally die life, have indicated the desirability of holding the iron above 1.25% in the aluminum base die casting alloys.

Dross and oxide inclusions are undoubtedly a factor to be considered in making aluminum die castings with a goose-neck type machine. However, with the exercise of reasonable care little trouble need be expected from this cause. Furthermore, serious inclusions will probably be found in aluminum press castings unless special precautions are observed in transferring the metal to the press machine. Reference is made in the article under discussion to the deleterious effect of "hard spots" on the machinability of die cast parts. Messrs. Gechter and Laird of the Western Electric Company reported gratifying results in machining studies of aluminum die castings in a paper before the December 1931 A. S. M. E. meeting. Difficult threading operations are commonly carried out on such critical parts as the transmitter case (see illustration) and receiver case in the handset telephone instrument. Somewhat smoother and more fully formed threads were obtained on parts cast from alloy No. 8 than on parts cast from alloy No. 4.

There can be little difference of opinion relative to the certainty of some porosity in the center of the wall in die cast parts produced by an air pressure machine. However, radiographic study of the initial castings produced by a given design of die, will usually point the way to modification in design which will reduce this internal porosity or suitably position the porosity to meet all of the requirements imposed on the part.

Inasmuch as recent studies on zinc base die casting alloys have shown that stability and permanence under humid conditions are primarily dependent upon purity of alloy, it is evident that satisfactoriness of either die castings or press castings made from zinc base alloys depends upon the care exercised in the purchase of the alloy and its handling in the plant. The No. XXI zinc alloy of the A. S. T. M., covered in Tentative Standard B86–31T, has been shown to meet permanence and stability requirements under test conditions equivalent to several years exposure at Key West, Florida.

Since the preparation of this specification, a new alloy known as Zamak No. 3 has been brought out by the New Jersey Zinc Company, which appears to be even better than A. S. T. M. alloy No. XXI in permanence of shape and dimensions although it does not possess quite as high initial strength as the No. XXI alloy. Studies made by the sponsoring company, which are corroborated by independent investigations in so far as they have been carried, indicate that this alloy will probably meet all permanence requirements of critical size and strength parts if the strains have been relieved in the castings by short aging periods at elevated temperatures prior to final machining and assembling.

The foregoing discussion is not intended to indicate that further improvements in the production of die castings are not desirable nor to question the value of press casting. The real field for press castings would appear to be the copper alloys which are not satisfactorily handled with the present goose-neck machines. Nevertheless, it is felt that any die casting development intended to compete with existing equipment in its present field should be examined on the basis of its merits when compared with the results obtainable from the conventional equipment when operated under the same control conditions used in demonstrating the new equipment. It should also be borne in mind that the high production rate possible with pressure die casting machines, and the consequent price economies, are essential requirements for any new casting equipment which may hope to more adequately meet the same need.

HARVEY A. ANDERSON

Metallurgical Development Engineer, Western Electric Company
Chicago, Ill.

January 4, 1932

◆ ◆ ◆ ◆ ◆

Editor, METALS & ALLOYS.

I have read with a great deal of interest Mr. Candy's very excellent article in the November issue, on "Automatic Arc Welding of Steel Sheets."

However, it seems to me that Mr. Candy has overlooked mentioning the latest development in the process of automatic welding, namely, automatic welding with the shielded arc.

It is common knowledge with those familiar with arc welding that the molten weld metal as it is being deposited has an affinity for oxygen and nitrogen. Since the arc stream is maintained in an atmosphere composed chiefly of these elements, oxidation proceeds at a high rate during the passage of the weld metal from electrode to work. In this way oxides and nitrides are formed in the weld metal. It is the presence of the oxides and nitrides in the weld metal which impairs its strength, ductility and resistance to corrosion.

If the molten weld metal is protected from contact with atmospheric oxygen and nitrogen during the process of deposition, the weld so produced will be free of oxides and nitrides. Thus an arc, *completely shielded*, from oxygen and nitrogen, deposits weld metal superior to that deposited by an ordinary arc.

Our company has developed and had in rather wide use the past several years, a process of automatic welding with the shielded arc. By its use the metal is completely shielded from the oxides and nitrides of the air while the metal is in a molten condition. As a result greater increased strength and ductility and resistance to corrosion is secured.

The test bars, illustrated in Fig. 1, were cut from 1/2 inch welded plates along the weld, in order, as near as possible, to obtain only the weld metal for testing purposes. The plates from which these test bars were cut were of average structural steel with ultimate tensile strength of approximately 55,000 lbs./in.², elastic limit of 30,000 lbs./in.² and elongation of 22% in 2 inches. The welds were produced by butt welding the 1/2 inch plates in the manner illustrated in Fig. 2, the filler metal being of the same composition as the plates.

From Table 1 it will be noted that the ultimate tensile strength of these welds all exceeded the maximum ultimate strength conceded to rolled steel, and in no less degree did the elastic limit of these welds exceed that of rolled steel, the average of 8 test pieces being, elastic limit 58,275 lbs./in.², ultimate strength 78,280 lbs./in.² and the average elongation 21%.

Table 1. Results of Pull Tests Made on Weld Metal 1/2 Inch Thick Welds Made by the Automatic Shielded Arc Process

Sample	Volts	Amps.	Lineal Ft. One Side	Lineal Ft. Both Sides	Elastic Limit lbs./in.²	Ultimate Strength lbs./in.²	Elongation in 2" %
A	32	425	45	22 1/2	65,400	83,900	19
B	34	400	45	22 1/2	53,500	73,600	25
C	36	400	45	22 1/2	54,400	73,600	12
D	38	375	45	22 1/2	59,900	78,100	17
P	32	425	60	30	59,100	81,700	25
Q	34	400	60	30	55,900	75,700	19
R	36	400	60	30	62,000	83,700	23
S	38	375	60	30	56,000	76,000	30
Average					58,275	78,287.5	21.25

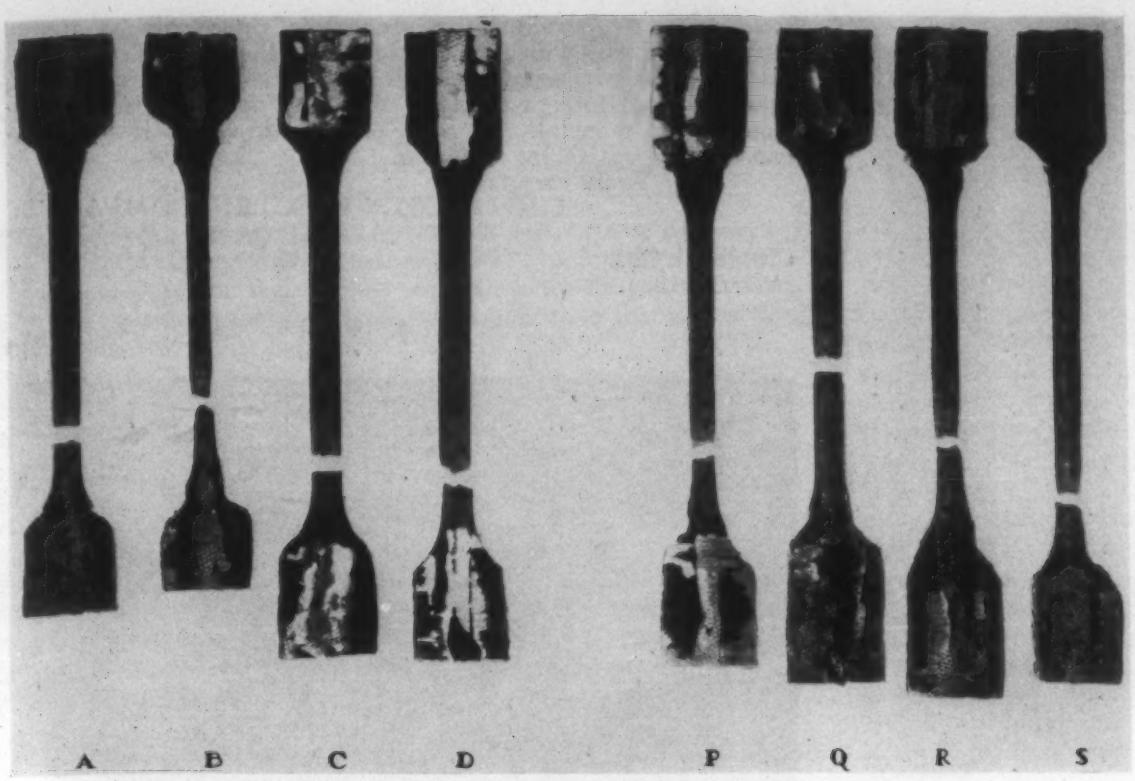


Fig. 1.

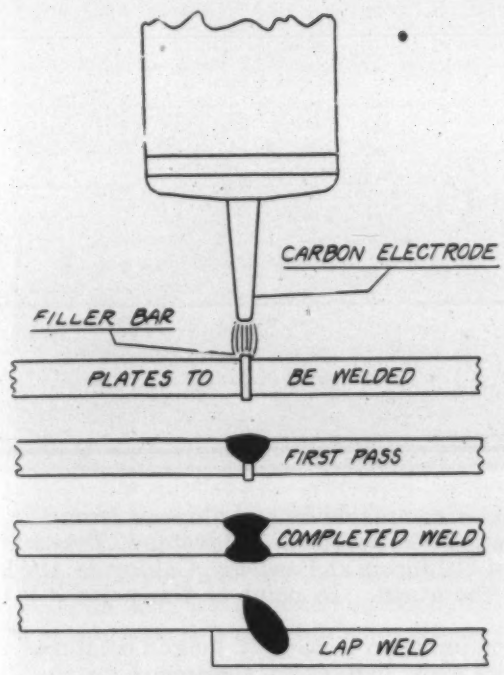


Fig. 2.

The test bars or samples shown in Fig. 3 were cut from one piece of $^1/_2$ inch plate, the result of butt welding two $^1/_2$ inch plates in the manner illustrated in Fig. 2. The filler metal used in welding was of the same composition as the plates. These samples were cut so that the weld occurred in the middle of each sample at right angles to longest dimension of the samples.

Sample H3 was tested without defacement of weld. The weld metal above the surface on one side of sample H2 was machined flush before testing. In the case of sample H1 both sides of the weld were machined flush with the plates. Samples H4, H6 and H5 were prepared for testing in the same manner as H1 with the exception that one, three and five holes, 0.119 inches in diameter, were drilled through the center of the weld metal in the respective samples in an attempt to make failure occur in the welds. The results of these tests are tabulated in Table 2.

An inspection of Fig. 3 will reveal that samples failed in the plate metal at a considerable distance from the welds. In the case of sample H5, which had 0.295 in.^{2} of weld metal removed before testing, the weld resisted a stress of 74,100 lbs./in.^{2} The only indication this tremendous stress imposed is revealed by a close inspection of Fig. 4 which shows the original drill holes in the weld have been pulled into the shape of ovals.

Pulling the holes, drilled through the weld, from round to oval graphically proves the high ductility of welds made by the automatic shielded arc process. Reference to Table 1 shows that the ductility of the weld metal compares favorably with the ductility of rolled steel. The usual percentage elongation in 2 inches in structural steel is 22, the average percentage of elongation in two inches in the weld samples, Fig. 1 and Table 2, is approximately 21.

The effects of corrosion on the weld metal and the parent metal are an important factor which should be given serious consideration in the determination of the proper automatic

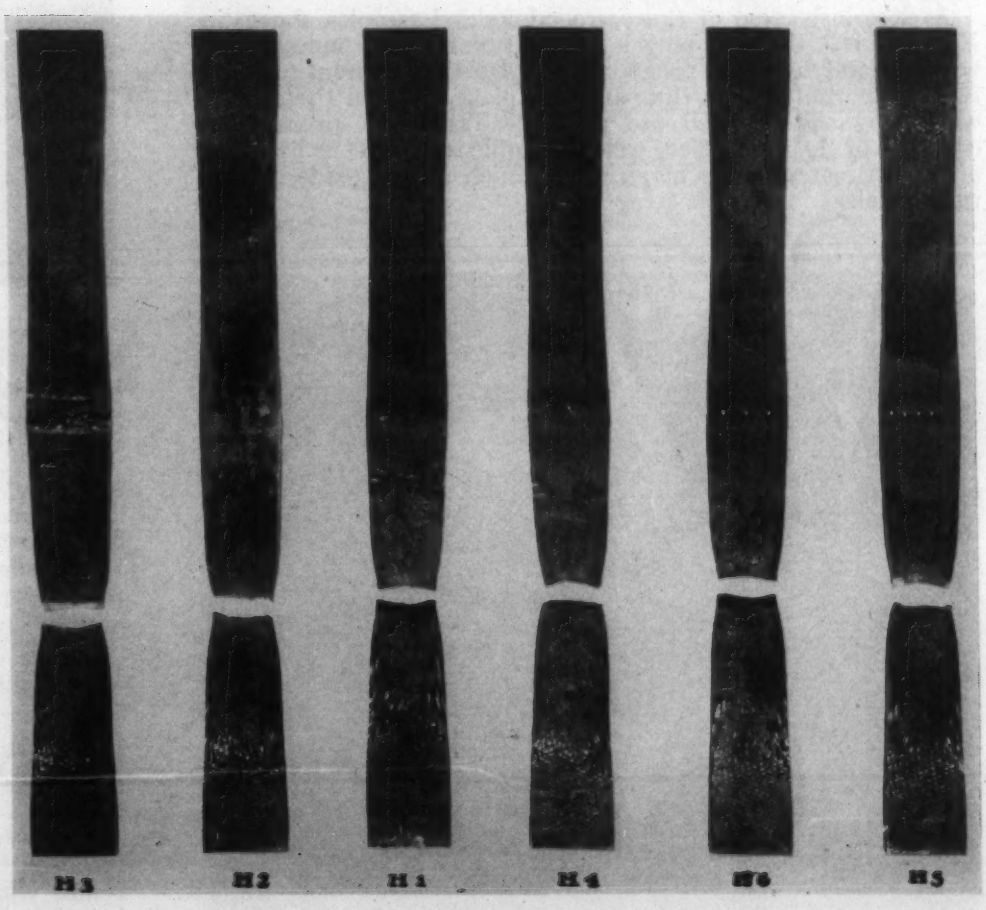


Fig. 3.

Table 2. Tabulation of Results of Tests Shown in Fig. 3.

Specimen No.	Preparation	Width of Specimen	Plate	Weld	Plate	Weld	Area Cut Out by Holes	Area of Weld Metal	Breaking Load	Ultimate Strength on Plate lbs./in.^{2}	Stress on Weld Metal	Break Occurred
H 3	Both beads left on	2.180	.485	.535	1.058	1.167	none	1.167	58,600	55,450	50,250	In plate
H 2	One bead ground off	2.187	.484	.509	1.059	1.113	none	1.113	58,400	55,200	52,450	In plate
H 1	Both beads ground off	2.183	.479	.480	1.048	1.049	none	1.049	58,400	55,800	55,750	In plate
H 4	Both beads off. One hole (.119" D) drilled through weld	2.185	.486	.501	1.062	1.095	.060	1.035	58,400	55,000	56,450	In plate
H 6	Both beads off. Three holes (.119" D) drilled through weld	2.186	.490	.488	1.070	1.068	.175	.893	59,000	55,150	66,100	In plate
H 5	Both beads off. Five holes (.119" D) drilled through weld	2.186	.487	.495	1.065	1.081	.295	.786	58,300	54,750	74,100	In plate

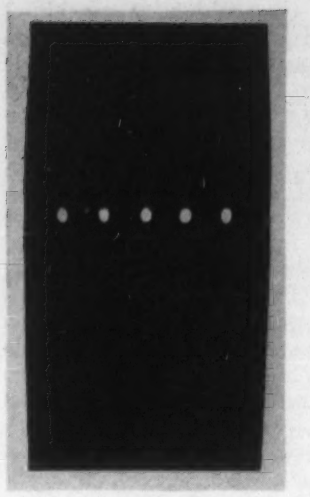


Fig. 4. (Above)

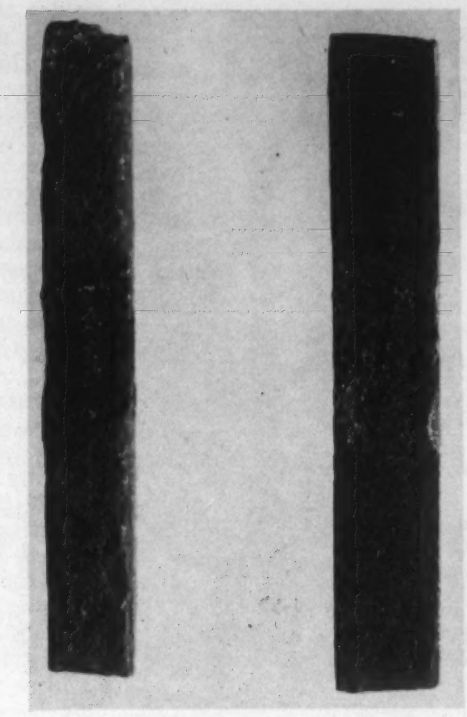
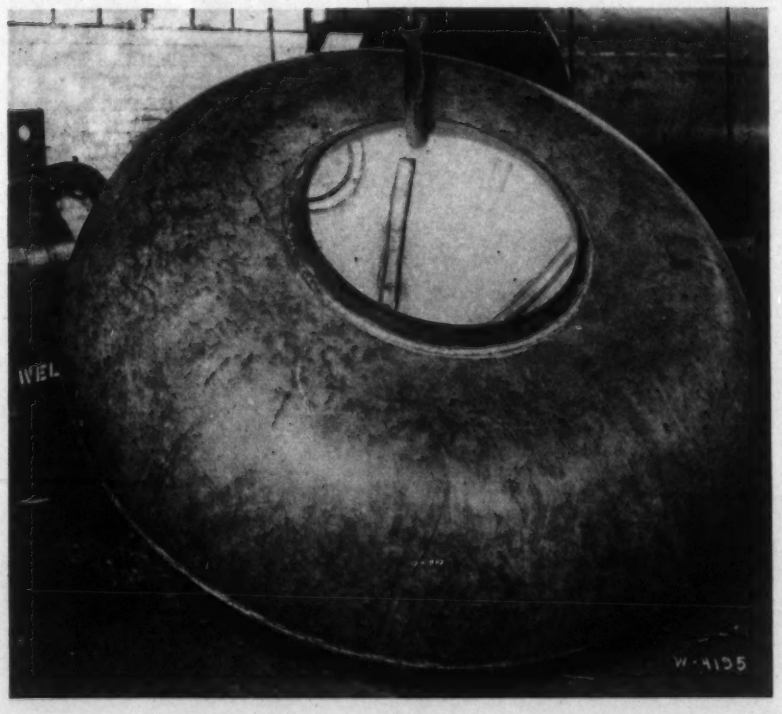


Fig. 5. (At Right)

arc welding process to employ. The rate of deterioration as a result of corrosion is often an influencing factor in the sale of an arc welded product, which in its use, is subjected to the causes of corrosion.

The effects of corrosion on $^1/_2$ inch plates butt welded by the metallic arc process and the shielded arc process, caused by an 120 hour immersion of test samples in a 20% solution of sulphuric acid are illustrated in Fig. 5. The welded test samples subjected to this particular corrosion test were cut from the same piece of structural steel plate.

A close inspection of the corroded welded samples shown in Fig. 5 reveals that not only is the corrosion of the metallic arc welded metal decidedly pronounced, but also the parent metal is far more corroded than the parent or plate metal in the sample welded by the shielded arc process. This very pronounced corrosion of the metallic arc welded sample is due to the presence of foreign material, the majority of which is iron oxide, in the weld metal.



Allegheny metal tumbling barrel fabricated with shielded arc process by Ohio Machine and Boiler Company of Cleveland.

When weld metal containing any foreign particles comes in contact with a liquid, such as a solution of sulphuric acid, an electrolytic action takes place due to the difference in potential between the particles of foreign material and the metal. The impurities being electro-negative will cause the electro-positive metal to dissolve. This is the action which has caused the deterioration of the parent metal of the metallic arc welded sample, Fig. 5. The effect of corrosion test upon the sample welded by the shielded arc process is practically negligible as compared with the effect upon the metallic arc welded sample.

Due to the inherent qualities of the shielded arc process, practically all foreign material such as iron oxide is excluded from the weld metal. Thus no electrolytic action is set up to cause deterioration by corrosion.

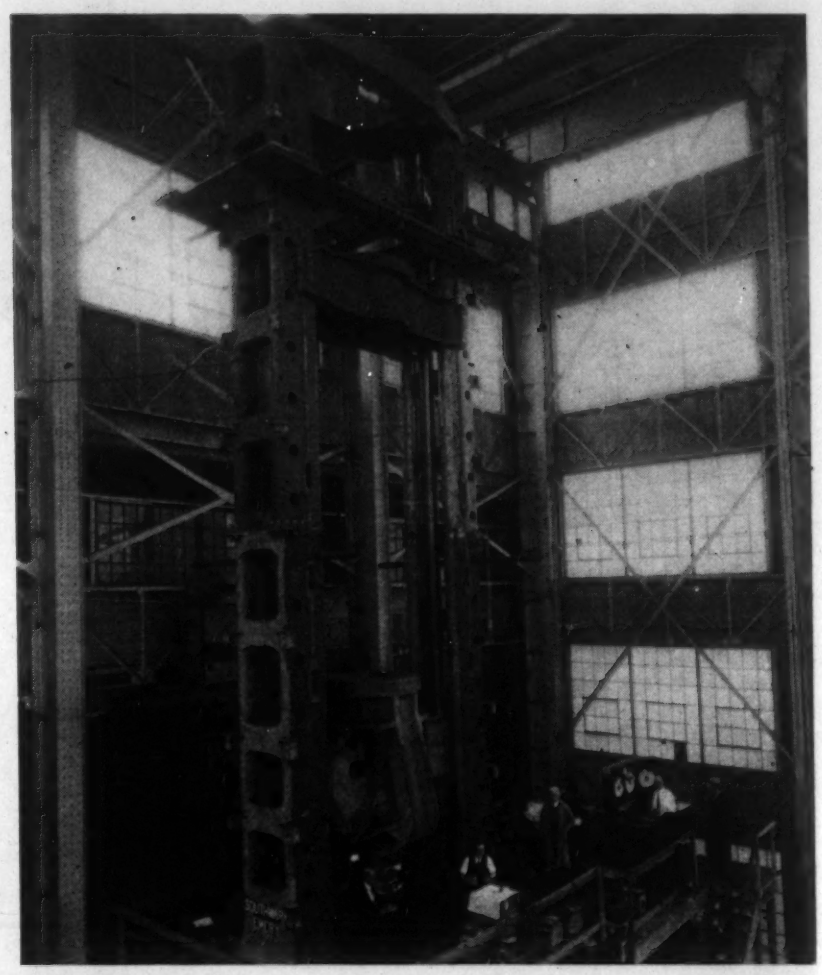
Yours very truly,

THE LINCOLN ELECTRIC COMPANY

A. F. Davis, *Vice President*

Cleveland, Ohio
Nov. 25, 1931.

◆ ◆ ◆



There has just been completed in and shipped from the shops of Baldwin-Southwark Corporation, Eddystone, Pennsylvania, to the University of California at Berkeley, California, the largest testing machine in the world. In point of dimension it is by far the largest.

It is able to test columns up to $33^1/_2$ ft. long in compression and up to 4,000,000 lbs. load, in tension specimens up to $33^1/_2$ ft. diminished by machine stroke and will apply loads up to 3,000,000 lbs. The spread between the columns is 10 ft. and the table is 12 ft. long. Since the table is level with the laboratory floor a truck may drive between the columns and the specimen be lifted directly from the truck body by the testing machine itself.

◆ ◆ ◆

Molybdenum Cushions Protect Tantalum Carbide Tools

A new method of applying carbide tips to cutting tools has recently been perfected by Ramet Corporation of America, North Chicago, Illinois, and is now being used in many of the tantalum carbide tools manufactured by this company and its licensees.

An insert of pure molybdenum metal is brazed between the steel shank and the tantalum carbide tip. Molybdenum having almost the same coefficient of expansion as the tantalum carbide alloy known as Ramet, the use of molybdenum inserts effectively prevents strains being set up or cracks developing in the cutting tips as tools cool after the brazing operation.

Such strains as may develop between the molybdenum insert and the steel shank are entirely absorbed by the molybdenum, due to its great ductility.

Molybdenum inserts are especially desirable in tools where the carbide tips are long, thin or of unusual shape; or where unusually severe conditions of operation are expected.

In small tools the tantalum carbide tip is now often mounted on a shank of solid molybdenum.

NEW RUSTLESS IRON ALLOY

BY R. P. DE VRIES*

THE new rustless iron alloy, Nevastain RA, represents a new departure in the field of rustless iron alloys, because it does not depend for its extreme corrosion resisting properties upon the maximum alloy content, but rather upon the minimum alloy content.

It was to be expected that the alloy of minimum content which would have the rustless properties of rustless iron containing, in many cases, two times the quantity of alloys this iron contains, would have to be made with due regard for selecting those proportions of alloy elements which contribute in very marked fashion to the maintenance of an incorrodible surface under many conditions of corrosive attack. The composition of this alloy is: 0.10% max. C; about 16% Cr; about 1% Si; about 1% Cu; about 0.40% Mn; max. P and S 0.03%. This alloy is manufactured into every form in which it is desirable to make rustless iron, ranging from castings with high corrosion resistance to the very thinnest strip, or wire of the smallest diameter.

WORKING

Hot Working

Its casting, forging and working properties in the stages of manufacture present the least difficulty of any known stainless iron. The alloy can be deformed hot without causing undue strains on rolling mills, forging presses, hammers, heading and upsetting machines, etc. For forging, the billet should be preheated and soaked at 1500° F. max.; the heat should then be raised slowly to 1900° to 2100° F. at a rate of 1 hour for each inch; commence forging at this temperature and finish above 1500° F. The stock can be reheated as often as necessary but should not be worked below 1500° F.

Cold Working

In cold working Nevastain RA does not work harden to the same extent as other stainless alloys. Therefore, it will cold roll, draw, upset and form with more ease and less mechanical trouble. This property is of paramount importance as it assures increased production and increased die life. Bending, forming and drawing can be readily accomplished. Annealed material should always be used for these operations and should either be in the pickled, ground or polished condition. For lubricants, water soluble drawing compounds, which can be washed off in hot water or hot water with soda ash, are generally satisfactory. When material is formed in a break, it is also advisable to use a lubricant which should be washed off carefully after the forming is completed. The maximum draw possible is a reduction of about 30% or, in other words, a 10″ diameter blank can be drawn in one operation into a 7″ diameter cup.

The alloy can be satisfactorily spun although not as easily as copper. It should be annealed and pickled between operations and should always receive a final anneal to relieve all strains. When properly annealed, Nevastain RA is tough and ductile at room temperature and the various operations of expanding, rolling, flanging and bending can be done at room temperature.

Nevastain RA is free machining, machining almost as easily as the high sulphur types of corrosion resistant steels. Feeds and speeds can be nearly the same as used with mild steel. It can be sheared, punched, sawed and drilled by ordinary methods.

JOINING

Soldering and Brazing

The alloy can be soldered without difficulty, producing firm and strong joints. For pickled finished material, the ordinary hydrochloric acid cut with zinc may be used. For polished articles, if there is difficulty in making the solder adhere, the surface may be dulled with the following solution:

Hydrochloric acid (HCl) 90 parts by weight
Ferric Chloride ($FeCl_3$) 50 parts by weight
Nitric Acid (HNO_3) 3 parts by weight

This solution should be allowed to set for 5 to 10 minutes, or longer if necessary, then wiped off. Tinning is then done in the usual way. If difficulty is still encountered an acid solution similar to the above, but which has been cut with zinc, should be used. After soldering, all traces of acid must be thoroughly removed by washing as the acid attacks the metal readily. In order to protect the metal from acid splashes during soldering and tinning the area adjoining the edges to be soldered or tinned should be protected with a grease or paraffin coating which afterwards should be removed. A large soldering iron which will have sufficient heat capacity to heat the metal thoroughly should be used. The alloy may also be brazed satisfactorily. For brazing, the usual procedure should be followed, taking precaution to have the metal thoroughly hot. A satisfactory flux for brazing may be made by mixing 4 parts by weight of borax with one part of ferric chloride in a solution of zinc chloride made by dissolving the zinc in muriatic acid to form a thick paste. A small quantity of this flux should be applied to the parts to be brazed before heating. Everdur or copper manganese are used as brazing materials.

Welding

Nevastain RA can be gas, electric arc, flash or spot welded without the tendency to grain growth inherent in the straight chromium types. It cannot be hammer welded. Welds in this metal remain tough and ductile, and full ductility can be restored in the weld by annealing at 1500° F. followed by air cooling. Since conditions vary with the work to be done, even a competent welder may need to experiment to develop just the right practice. The following instructions are broad and are designed to fit the average condition:

For acetylene welding, bare (uncoated) rods must be used, the size of the rod being approximately equal (up to about 3/16″) to the thickness of the metal to be welded. With plates and other heavy material, chamfer the edges to be welded and place these a small distance apart. Build up a bead between these edges, keeping the flame of the torch pointed in the direction of the welding so as to preheat the work. Do not attempt to go over the weld or puddle it. A slight excess of oxygen should be used so that the flame will be neutral. The flame should be no larger than necessary for the work to be done. A neutral short flame can only be retained by the use of a slight excess of oxygen. A long, yellow flame always indicates an excess of acetylene which will increase the carbon content of the metal in the weld. This produces not only a brittle weld, due to air hardening, but also a weld of lessened resistance to corrosion. For electric (arc) welding, coated welding rods must be used. Adjust polarity so that the electrode is the positive and the work the negative terminal. Also arrange the work so that the welding will be done in the direction from which the current is flowing. In other words, "Buck the current." The welding machines should be regulated to give the following current:

1/8″ rod	40–45	volts	open	circuit	with	75–100 amp.
5/32″ rod	50–60	"	"	"	"	100–125 amp.
3/16″ rod	55–65	"	"	"	"	150–175 amp.
1/4″ rod	70–80	"	"	"	"	225–300 amp.

If arc is not steady increase the amperage. As in acetylene welding, the thickness of the rod should approximate (up to about 3/16″) that of the material being welded. When laying a heavy bead, it is advisable whenever possible to lay several beads, one on top of the other, rather than to attempt to lay a very heavy bead at one operation. It is important to remove the slag formed by scraping, wire brushing or with an air hammer and blunt tool before laying succeeding beads. While welds made with Nevastain RA are fairly tough and ductile the anneal given previously is recommended whenever possible. Either furnace or torch anneal can be used. This treatment will produce homogeneity in the metal and weld. Welding rods may be either Nevastain RA or Nevastain KA2S.

Riveting

Nevastain RA is a very satisfactory material for rivets. It hardens but slightly on rapid cooling. Therefore, the accurate temperature control required for straight chromium iron rivets is not necessary. Nevastain RA rivets may be driven hot at temperatures between 1450–1550° F. or cold with equal success, the rivet remaining tough and dependable. Annealed rivets, however, should be used when driven cold.

SURFACE TREATMENTS

Pickling for Removal of Scale

The standard pickling treatments which produce the usual gray pickled finish are as follows: A solution of 10% hydrochloric acid plus 10% sulphuric acid at a temperature between 170° and 190° F. Where such acid is not available, a solution containing about 10% sulphuric acid and 6% to 12% rock salt by weight should be used at 160–190° F. The effect of the rock salt is to liberate hydrochloric acid. After pickling rinse thoroughly and dip in a solution of nitric acid, 10% strength at 130° F. and wash carefully in hot water.

* Metallurgist, Ludlum Steel Company.

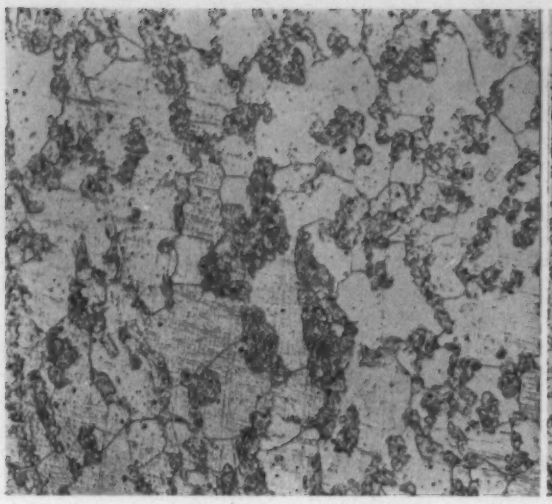


Fig. 1. Slab 2″ × 7″, hot rolled and air cooled from 1650° F. Tensile strength 117,200 lbs./in.², elongation in 2″ 15%, Rockwell B 95. Magnification 150 ×.

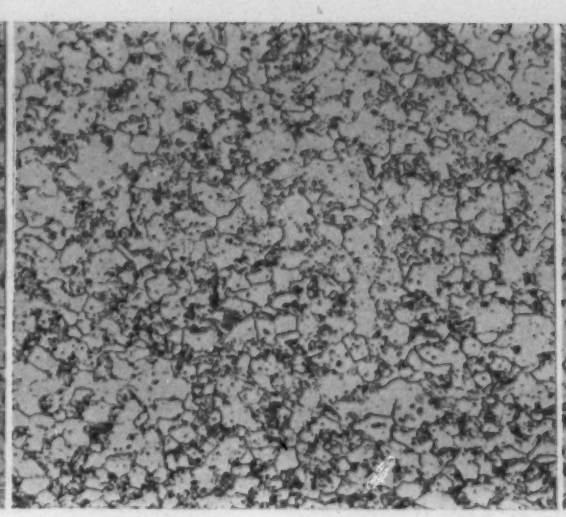


Fig. 2. 0.047″ Strip, cold rolled from slab in Fig. 1 and air cooled from 1625° F. Tensile strength 110,000 lbs./in.², elongation in 2″ 23%, Rockwell B 84. Magnification 150 ×.

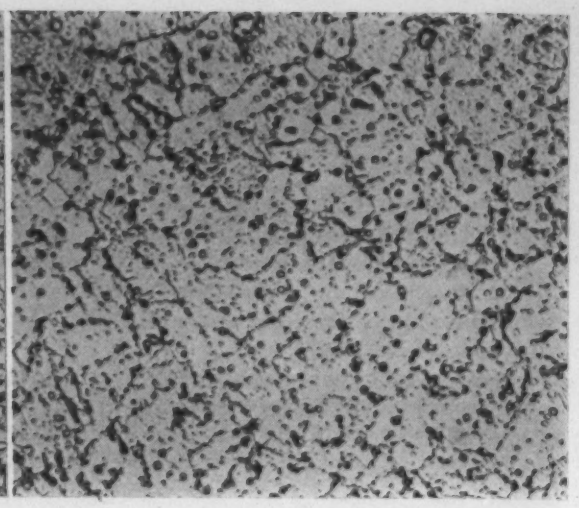


Fig. 3. Tube 2 1/16″ O.D. × 1 3/4″ I.D. as received. Magnification, 500 ×.

Passivating of Surfaces

It will be noted that in the foregoing pickling instructions a nitric acid dip is recommended after pickling. The nitric acid treatment will remove all foreign substances which might have become imbedded in the surface during rolling, forming, drawing, breaking, shearing, punching or polishing, and which may produce rust or corrosion spots. It is therefore recommended that fabricators use this same treatment as a precautionary measure on all fabricated parts. This treatment is generally carried out as follows: Fabricated parts are cleaned and submerged in a 5 to 10% nitric acid solution at about 140° F. for 10 minutes and are then washed in hot water and dried.

Grinding and Polishing

The amount of grinding and polishing required depends very much on the mill finish of the material used. In general, a hot rolled pickled sheet requires a No. 120 to No. 150, No. 180 to No. 200 grinding whereas sheets and strip that have received some cold rolling require No. 180 to No. 200 grind or less. It is essential that all marks and scratches from previous grinding be removed with each finer grinding operation. Dry grinding should never be used. The best method to use is a grease wheel. Due to the fact that Nevastain RA is magnetic, a magnetic chuck can be used. Another important factor is the speed of the wheel. Speeds for grinding should not exceed 8000 ft./min.; 6000 to 8000 ft. being best. This on a 14″ wheel will require a spindle speed of about 1750–1800 R.P.M. For buffing a speed of about 9000 to 10,000 ft./min. should be used, which, for a 14″ buffing wheel will mean a spindle speed of about 2400 R.P.M. A Tampico brushing should be used between polishing and buffing. Experience has shown that annealing and pickling, if properly carried out, will not destroy a ground finish imparted to the stock.

If satin or brush finish is desired, use Tampico brushing or buff with flour emery in water. All grinding and polishing should be done with the least possible pressure. Never clean Nevastain RA with a steel wire brush. Always use a brush of the same material or a non-metallic brush.

The alloy polishes readily to a high permanent luster with a beautiful blue white color.

HEAT TREATMENT

Nevastain RA does not require high temperature heat treatment for annealing or to relieve forging or drawing strains. Full ductility is obtained at normal annealing temperature. It also has the very desirable property of responding to heat treatment. This property permits a treatment for higher strength and hardness when required.

To secure the best service from Nevastain RA it is essential that it be used in the annealed or heat treated condition. The steel then has its greatest resistance to corrosion and oxidation. In the annealed state it is most ductile and, therefore, in the best condition for bending, forming, deep drawing, etc. Annealing generally consists of uniformly heating the steel in a neutral atmosphere to 1475–1525° F. followed by air cooling. In the heat treated condition, Nevastain RA possesses its maximum strength plus hardness, also best machinability. The heat treatment consists of heating the steel uniformly to 1700–1750° F., quench in water, or oil, then draw to requirements, generally 1000–1200° F. The physical properties can be varied from extreme softness and high ductility to a hardness in the cold rolled condition which compares with that of piano wire. The strength, likewise, can be varied from 70,000 to 350,000 lbs./in.²

Table 2.—Average Tensile Properties—Sheet Stock

.040″ — .042″ thick

	Hot Rolled, Annealed and Pickled	Cold Rolled, Annealed and Pickled Longitudinal	Transverse
Ultimate Strength (lbs./in.²)	77,000–80,000	70,000–75,000	70,000–74,000
Yield Point (0.02″ by Dividers)	57,000–64,000	50,000–54,000	50,000–52,000
Elongation % in 2″	24–26	26–30	26–28.5
% in 4″	16–18	20–22	20–21
% in 6″	13.5–15.5	16.5–19.5	16.5–18
Rockwell B Scale	79–83	81–83	81–83
Erichsen Value	8.80–9.00	Average 9.0	

Table 3.—Average Properties of Heat Treated Nevastain Ra at Elevated Temperatures

	Short Time Test, Slow Rate of Pull				
Temperature	75° F.	500° F.	1000° F.	1400° F.	1500° F.
Tensile Strength	91,000	80,000	63,000	11,850	6250
Yield Point	67,000	56,000	53,000	10,350	..
Elongation	29	25.5	26.5	37	48.5
% Reduction in Area	69.3	62.6	60	73	77.3

Table 4.—Other Properties of Nevastain Ra

Specific Gravity	7.67
Melting Point	2750° F.
Thermal Conductivity	0.080 cal. per cm.³ × 1° C. × 1 sec.
Scaling Point for Continuous Operation	1450° F. maximum
Coefficient of Linear Expansion	0.000010 per 1° C. up to 500° C. 0.000011 per 1° C. up to 1000° C.

APPLICATION

It has a wide application, therefore, in almost every field in which rustless iron is used. It has been used for architectural

Table 1.—Average Tensile Properties—Bar Stock

		Annealed	Oil Quenched from 1750° F. Tempered at		
	Hot Rolled	at 1500° F.	1200° F.	1350° F.	1400° F.
Ultimate Strength (lbs./in.²)	100,000–130,000	75,000–90,000	103,000	89,000	90,000
Yield Point (lbs./in.²)	50,000– 70,000	40,000–50,000	98,000	66,000	67,000
Elongation % in 2″	17–25	30–40	25	38	30
Reduction of Area %	45–65	60–75	63.5	69.5	69
Brinell	220–260	150–170	217	192	187
Rockwell B Scale	90–103	80–90	98	92	90

ornamental work with success which has not been approached by any other alloy, both on account of its easy working and on account of its beautiful lustre and color obtained by cold rolling and polishing, or other means.

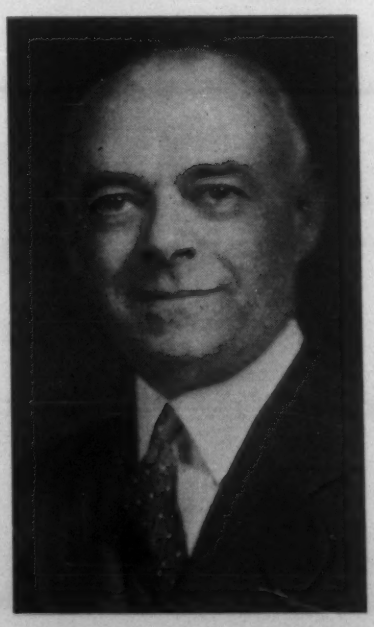
In the field of chemical corrosion resistance, it has wide application in many industries and in many forms, such as castings, tubes, rods, strip and sheet.

◆ ◆ ◆

T. H. Wickenden, since 1922 in charge of the International Nickel Company's development work in the automotive and aeronautical fields, has been appointed Assistant Manager of Development and Research. Trained at the University of Michigan, he became metallurgist for the Studebaker Corporation which in due course put him in charge of the engineering department at the South Bend, Ind., plant. Later Mr. Wickenden was one of the engineering group which designed the first Chrysler car.

H. J. French, since 1929 a member of the International Nickel Company's research staff at its laboratory in Bayonne, N. J., has been transferred to the Development and Research Department in New York to take charge of development work in steel and iron. A graduate of the School of Mines at Columbia University, Mr. French was senior metallurgist at the United States Bureau of Standards before joining International Nickel. Widely known for his technical work in steel applications and practices, he was awarded in 1930 the Henry M. Howe Medal of the American Society for Steel Treating. Mr. French is a member of the Editorial Advisory Board of METALS & ALLOYS.

R. **L. Suhl,** for the past three years assistant to the late Frederick S. Jordan, succeeds him as Manager of the Nickel Sales Department of The International Nickel Co., Inc. **Ransom Cooper, Jr., Walter C. Kerrigan and Charles McKnight** have been appointed as Mr. Suhl's assistants. All four men are veterans of the nickel industry Mr. Suhl joined the original International Nickel Co. on May 1, 1903, as a laboratory assistant in the Bayonne, N. J., refinery. He was made superintendent of electrolytic refining in 1908 and during the World War had, as superintendent of the oxide division, entire charge of the roasting and leaching of the ores. In 1920 he joined the headquarters staff of the company in New York as a development engineer, and continued as a member of the Development and Research Department until 1928 when he became assistant sales manager of the Nickel Department. Mr. Cooper was vice-president and sales manager of the American Mond Nickel Co. before joining International Nickel in 1929; Mr. Kerrigan had previously been general manager of the United States Nickel Co. at New Brunswick, N. J., before making his present connection two years ago, and Mr. McKnight has been since 1922 in charge of alloy steel development for International Nickel.



Henry H. Peck, formerly with the Standard Steel Works Company of Burnham, Pa., has joined Lukenweld, Inc., Coatesville, Pa., as Manager of Sales. Mr. Peck for many years was associated with iron and steel foundries throughout the country, principally in the sale of castings. Mr. Peck succeeds Mr. John S. Bleecker, formerly in charge of sales for Lukenweld, Inc. Mr. Bleecker has been appointed Manager of Sales Research and Advertising for Lukens Steel Company and its divisions, Lukenweld, Inc., and By-Products Steel Corporation.

Picklands, Mather & Co., Cleveland, have announced the acquisition of the pig iron and coke sales business of Pickands, Brown & Co., Chicago.

◆ ◆ ◆

Savings of approximately $16,000 a year are realized from salvaging metals from ashes produced in the scrap incinerator at the Schenectady plant of the General Electric Company.

The ashes, instead of being loaded into a dump car and delivered to the dump, are first run through a ball mill, where they are pulverized, the larger pieces of metal passing out of the mill and over a magnetic separator, which separates the magnetic scrap from the non-magnetic material, which consists of copper, brass, aluminum, etc.

The finer material which is discharged from the ball mill passes over an inclined, longitudinally grooved "concentrating table," which has a stream of water flowing crosswise of the material.

The metal being heavier than the ash, slides down the bottoms of the grooves and falls off the lower end of the table, while the ash is washed off the side of the table and is then pumped through a "dewatering cone" which discharges the dewatered ash in a dump car. The ash is used for filling in low ground and the metals and concentrates are sent to the smelter or sold as scrap.

By this method approximately 100,000 pounds of ashes are ground and washed and from 20,000 to 25,000 pounds of metals and high grade smelting material is recovered each month.

◆ ◆ ◆

At the recent meeting in Cleveland of A. S. T. M. Committee C-8 on Refractories several interesting developments in the refractory testing field were discussed.

The question of having the committee adopt a standard sieve scale and methods of making both wet and dry sieve analyses was presented. It was pointed out that there is a necessity for these steps because increasing quantities of ground and crushed refractory materials are being bought on screen specifications. After some discussion the matter was referred to the Subcommittee on Research for recommendations at the next committee meeting. The chairman of this Research Committee is S. M. Phelps, Director of Research and Tests, Mellon Institute of Industrial Research, Pittsburgh.

Measurement of Warpage

The Subcommittee on Precision and Tolerance presented a report covering the possible adoption of a method and device for measuring warpage. For the measurement of this property, a standard measuring wedge, known as the warpage meter, has been developed at the Mellon Institute. The subcommittee approved the use of this meter but recognized the fact that further data on its construction, manufacture and cost must be obtained.

Standards for Refractory Insulating Materials

The importance of the formulation of standards to measure the different physical properties of refractory heat insulating materials, in addition to their characteristic property of retarded heat transfer, was pointed out at a previous meeting of Committee C-8. It was decided to proceed with this work and a suggestion was made that the committee extend its membership to include men particularly qualified in the manufacture, use and knowledge of properties of these refractory materials.

Of the various physical characteristics of refractory insulating materials which are of interest, the following were mentioned:

1. Cold crushing strength
2. Transverse strength
3. Shrinkage
4. Impact resistance
5. Hardness
6. Crushing strength under heat
7. Expansion under heat.

The urgent need of research and standardization work in this refractory heat insulating field is evident. The importance of insulating brick which are at the same time refractory is growing. Several such brick have made their appearance in the market in the past year. They are an entirely new product inasmuch as they are for service at a temperature of about 2500° F. Two or three of the brick which have recently been developed appear to be as refractory as high-grade fire-clay brick and show little shrinkage when the temperature is as high as 3000° F.

About the Cumulative Index

In the January issue we announced that we planned to issue an index of all METALS & ALLOYS Abstracts up to and including December 1931, prepared by a trained staff, and to be published early in 1932. It will be the same page size as METALS & ALLOYS and will cover 7824 abstracts of articles and books.

To date we have received 150 orders for this

CUMULATIVE INDEX

but we must have 400 more before we can start on the work. The price we ask ($1.00) covers only the printing. If you want to be certain of having a copy, send us your order now because we will make just enough for those who tell us they want them—there will be no "extras."

Just a minute— Please!

Show your associates, the ones who are not already subscribers to METALS & ALLOYS, a copy of the publication and tell them how they can save both time and money by subscribing—

NOW

Tell them that reading the metallurgical abstracts in METALS & ALLOYS, in addition to saving their time and their money, will give them the satisfaction of knowing that they are keeping abreast of the latest developments in their field just as surely as though they subscribed to, and read, all the publications covered by our fifty section editors and abstractors.

If two or more of them will send in their subscriptions together they may take advantage of the following special rates:

2 separate one-year subscriptions - - -	$5.00
3 separate one-year subscriptions - - -	6.00
4 separate one-year subscriptions - - -	7.00
5 separate one-year subscriptions - - -	7.50

METALS & ALLOYS
419 Fourth Avenue, New York, N. Y.

Enter or renew subscriptions for the following and invoice them directly:

Name..... Address.....

Name..... Address.....

Name..... Address.....

Name..... Address.....

Name..... Address.....

Signed.....

USEFUL BOOKS

ZIRCONIUM AND ITS COMPOUNDS

FRANCIS P. VENABLE — *A. C. S. Monograph No. 5*

173 Pages **$3.00**

The only book in English completely covering the occurrence, preparation, properties and applications of this element and its compounds. A list of important patents and an extensive bibliography are appended.

MOLYBDENUM, CERIUM AND RELATED ALLOY STEELS

H. W. GILLETT AND E. L. MACK — *A. C. S. Monograph No. 22*

299 Pages **Illustrated** **$4.25**

Describes the sources and chemical properties of the alloying materials and the physical and engineering properties of the alloy steels containing them.

TITANIUM, with Special Reference to the Analysis of Titaniferous Substances

WILLIAM M. THORNTON, JR. — *A. C. S. Monograph No. 33*

262 Pages **Illustrated** **$3.75**

Following an introductory portion covering the occurrence, general chemistry and industrial applications of titanium, the author presents an exhaustive treatise on the detection and estimation of titanium in its various associations, having particularly in mind the requirements of the practical analyst.

PROTECTIVE METALLIC COATINGS

HENRY S. RAWDON — *A. C. S. Monograph No. 40*

277 Pages **Illustrated** **$4.25**

An up-to-date survey of the field of corrosion prevention, or retardation, particularly of iron and steel, especially useful to the engineer, manufacturer, metallurgist and chemist. The various coating methods—hot-dipping, cementation, metal spraying, electroplating, alloying, chemical treatment, etc.—are described in detail, as are the coatings produced by these methods using zinc, tin, copper, nickel, chromium and other metals. Methods of testing such coatings are given and an extensive bibliography is appended.

TIN

C. L. MANTELL — *A. C. S. Monograph No. 51*

353 Pages **Illustrated** **$5.25**

A comprehensive survey of the various phases of the production of tin from its ores to its commercial application. The history, physical and chemical properties, and the production, distribution, and consumption of the metal have been presented and discussed from the viewpoint of the chemist, the metallurgist, and the chemical engineer rather than from the viewpoint of the mining engineer or the mechanical engineer. Secondary tin and detinning of tin-plate scrap has been treated from the economic as well as from the metallurgical and chemical viewpoint.

BEARING METALS AND BEARINGS

W. M. CORSE — *A. C. S Monograph No. 53*

383 Pages **Illustrated** **$5.25**

A survey of the fundamental principles and practices involved in the selection of bearings and bearing metals, together with a bibliography of reference literature from 1900-1928 inclusive.

SHEET STEEL AND TIN PLATE

R. W. SHANNON

285 Pages **Illustrated** **$5.00**

A practical work on the utilization of sheet steel and tin plate in the steel-fabricating arts. The essential facts concerning sheet steel and tin plate are clearly set forth in everyday language, enabling the layman to gain therefrom an insight into the possibilities and limitations of these important kinds of steel products, which will permit him to understand present day uses better, and possibly to visualize new uses, for these materials.

METALLOGRAPHY

GUSTAVE TAMMANN

Translated from the Third German Edition
By Reginald S. Dean and Leslie A. Swenson

388 Pages **Illustrated** **$7.00**

A textbook. A translation of the leading German treatise on this subject covering most completely the chemistry and physics of metals and their alloys. The author has involved a system of metallographic theory which is distinct from that of any other school of metallurgists.

The CHEMICAL CATALOG COMPANY, *Inc.*

419 FOURTH AVENUE NEW YORK, U. S. A.